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RESERVE

A Summary of Current Program and
Preliminary Report of Progress

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HORTICULTURAL CROPS RESEARCH
of the
United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

Section B

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of foods available to consumers change constantly with the adoption of new practices of production, processing, and marketing. Changing constantly also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, on the nutrient and other values of foods and on how to conserve or enhance these values in household and institutional preparation and processing. Periodic surveys of the kinds, amounts, and costs of foods consumed by different population groups and individuals also are essential to evaluate the nutritional adequacy of diets and to give the guidance needed for effective programs of nutrition education. Information from such surveys provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and consumer use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service -- the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done at Beltsville and Hyattsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas is 77.5 man-years. It is estimated that approximately 26.9 man-years is concerned with studies related to horticultural products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 30.2 professional man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to vegetables are considered in this report.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Nutrient value of foods. Research on the nutritive composition of food is often concentrated on locally produced commodities. With the increase of processed and prepared foods, much of the evaluation is related not only to genetic factors and feeding practices but to changes induced by processing and storage to arrive at a value which represents the dietary contribution of the product.

The chemical structure of fats and lipids in food stuffs and the changes involved in processing, holding, and final preparation are receiving special attention as the problem of fats in human nutrition continues an active area of research and speculation. Protein and amino acid content and alteration with heat processing remain active research areas. The importance of conjugates of protein and lipids especially as they are formed in food processing, is being investigated in relation to their nutritive characteristics. Research has been directed toward the vitamin content of food as related to inherent inhibitory and stimulatory factors.

The total program in this area includes 38 projects in 24 States and is comprised of approximately 27.3 professional man-years.

Properties related to quality and consumer use of food. Research on food preparation for consumer use may be accompanied by measures of quality from the raw state, through handling and processing for marketing, to final home and institutional service. Special measures characterize certain classes of products; e.g., vitamin assays, enzymatic activity, water binding capacity, and changes in structural tissues.

A portion of the work is directed to the production, processing, and storage for fruits and vegetables. Variables which affect the initial products are under study and include growing practices and genetic factors. Conditions of processing relate to freezing temperature, duration and temperature of storage, shelf life, and the effect of light.

Special research emphasis is on the physical and chemical alterations involved in home preparation of foods. This work is carried out with the objective of having foods of maximum quality and nutritional value for

final consumption. These researches include: suitable methods for home freezing and storage of fresh and precooked foods; micro-wave preparation of vegetables and the chemical changes involved; and flavor characterization in frozen and stored products by means of vapor component identification.

Many of these same factors are being investigated for institutional preparation where the quantities involved impose special conditions.

The State program in this area includes 55 projects in 27 States and involves approximately 50.5 professional man-years. This is a partial report of the State Experiment Station program in food science and includes the work undertaken and participated in by Departments of Home Economics. For research on food and fiber, see the reports of the Utilization Research and Development Divisions, and Clothing and Housing Division.

Food consumption and diet appraisal. The State program in food consumption and diet appraisal extends the work of the Department to selected segments of the population or to smaller geographic areas. One continuing investigation in the North Central Region is planned to yield information regarding food purchase and consumption patterns of families with preschool children. This research will provide information of use to both consumer education and market interests.

In the Western region an ongoing study of consumer response at the retail level to varying quality factors in selected fruits and vegetables will be completed this year. A continuing consumer panel in a Southern metropolitan area is providing information on purchase patterns, including data on changes in form, amount, kind, expenditure, and nutritive value of foods purchased. Attempt is made to identify and quantify in a relative sense the factors effecting change.

Currently 16 States are contributing to the Experiment Station program in this area which totals 22.7 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Nutritive and Other Consumer Values of Horticultural Products

1. Potato products. Studies are nearing completion on the proximate composition and energy value of different market forms of potato products as purchased and as prepared for serving. New ways of preparing and packaging potato products for the consumer give these data importance. French fries, chips, puffs, patties, and hash browned potatoes are included. A manuscript reporting results will be prepared.

Plans were developed to initiate research on the effects of the use of pesticides during production of potatoes upon their palatability and related biochemical properties (See also A.2., par. 3 below).

2. Vegetables. Snap beans of the Topcrop variety grown in 1964 in soil treated with the systemic insecticides Di-Syston and phorate were similar to those grown in untreated soil as shown by panel evaluations of color, flavor, and texture, and by physical measurements of color and shear (tenderness) in the cooked snap beans. In 1963, the phorate-treated beans had slightly more off-flavor and slightly lighter color than the control or Di-Syston treatment.

In other studies, preparation problems encountered in school food service units receiving dry beans distributed by USDA are being investigated. Grade 1 and Grade 3 pinto beans have been cooked in large quantity with and without sodium bicarbonate and with and without discarding the soaking water to determine cooking time, tenderness, appearance, and flavor characteristics. Other bean varieties to be investigated are great northern, red kidney, and pea beans.

Under contract with National Canners Association Research Foundation at Berkeley, California and Washington, D. C., research was initiated to determine the extent to which pesticide residues are removed by various methods of preparation, cooking, and processing of selected vegetables, and to provide information for use in the development of effective food preparation procedures to remove or reduce pesticide residues in vegetables prepared for eating. Washing, blanching, peeling, and cooking may all be expected to modify the residue content of vegetables and to influence the amount and type of transformation products that are derived from the parent chemical compound of the pesticide. The vegetables chosen for the study include spinach, green beans, potatoes, and tomatoes which require different preparation and cooking procedures. Vegetables will be treated during production with selected insecticides such as DDT, malathion, and Sevin, chosen to represent a chlorinated hydrocarbon, an organic thiophosphate, and a carbamate-type compound with different solubilities and ease of degradation.

3. Fruits and nuts. Analyses of fruits and nuts for content of three forms of vitamin B₆ have shown that most fresh fruits (including citrus, deciduous, melons, and subtropical) contained less than 1 microgram of vitamin B₆ per gram of fruit. Notable exceptions were avocados and bananas which had 4 and 6 micrograms per gram, respectively. Dried fruits contained 1 to 4 micrograms of vitamin B₆ per gram, and nuts ranged from 1 to 6.5 micrograms per gram. Coconut was found to be quite low, 0.5 microgram per gram. Generally, fruits and nuts contained a higher proportion of pyridoxine than of the other two forms of vitamin B₆, namely pyridoxal and pyridoxamine. A manuscript reporting the data is in preparation.

4. Fruits. Investigations have been completed of the relationship between eating quality and certain acids, sugars, and other constituents of peaches, strawberries, and raspberries. Effects of ripeness, variety, season, and changes resulting from household freezing and storage were studied.

Ten varieties of freestone peaches were included over a 3-year period. Four levels of ripeness were studied in the final two seasons. With increased ripeness of the fruit, there were decreases in malic and citric acids and increases in quinic acid and in pH. Sucrose content increased but glucose and fructose did not. The amount of protopectin decreased with increasing ripeness of the fruit. There were significant differences in many of the quality factors investigated that could be related to variety and season of growth. In general, the earlier maturing varieties were higher in acid content and lower in pH and sugars than were the later maturing varieties. When the fruit was frozen and stored for 8 months at 0° F. to -10° F., there were significant decreases in malic acid and quinic acid content and in pH. Sugar-acid ratios, sugars, pH, soluble solids, and citric acid-malic acid ratios were significantly correlated with panel flavor scores.

There were significant changes in composition with increased ripeness of strawberries. Citric acid, malic acid, alcohol insoluble solids, pectin, and shear force values decreased. Malic acid content decreased more rapidly than did that of citric acid. Reducing sugars, soluble solids, pH values, and panel flavor scores increased. There were significant differences in many of the quality factors that could be related to variety or season of growth. Sugar content, sugar-acid ratios, soluble solids, citric acid-malic acid ratios, and pH values were significantly correlated with panel flavor scores, and pectin and shear force values with panel texture scores. The results for peaches and strawberries have been prepared for publication and those for raspberries are being prepared.

Plans have been developed for research on the effects of the application of halogen-containing and systemic insecticides during production on the palatability, composition, and related biochemical properties of strawberries.

The effect of successive yearly herbicide treatments during crop production on the eating quality of frozen blueberries, raw apples, and applesauce was investigated. Blueberries grown in diuron- and simazine-treated soil were evaluated for flavor, pH, and soluble solids. The blueberries from plots treated with 2 lb/acre of diuron both in the spring and fall or 4 lb/acre diuron only in the spring had significantly more off-flavor scores than those treated with 2 lb/acre diuron in the spring. The berries from the spring-fall 2 lb/acre treatment with diuron were significantly different in flavor from the control. Blueberries from the simazine treatments received a small number of off-flavor scores and were not different from the control. Herbicide treatment with diuron or simazine did not change the pH or soluble solids content of the blueberries.

Apples grown in herbicide-treated plots were significantly less tender than apples from control plots when the treatments were diuron, simazine, CIPC (isopropyl N (3-chlorophenyl) carbamate) or diuron plus CIPC, as shown by pounds force required to shear raw apple slices. Apples from amitrole-treated plots were similar to the control apples. According to panel evaluations of raw apples and applesauce, herbicide treatment did not affect flavor adversely when compared with apples grown in control plots. However, applesauce from apples grown in amitrole-treated plots received significantly more off-flavor scores than sauce made from apples grown in diuron-treated plots.

Research continued on the detection, site, and character of the lipid constituents in the edible cell walls of cantaloupes and selected fruits. Several methods have been used and adapted for staining and extracting lipids and other constituents associated with lipid-like materials in the cell walls. The findings will be prepared for publication. The above methods are being used to determine the relationship of the cell wall lipids to texture of fresh, frozen, and frozen stored cantaloupe. If indicated, the study will be extended to include other plant materials.

Investigations have been completed of the relationship between eating quality and certain acid, sugar, soluble solids, and other constituents of fresh and frozen cantaloupe. A manuscript is being prepared.

5. Sugar extractants from fruits and vegetables. Study of procedures for the extraction of sugars from fruits and vegetables is continuing. Samples of apples and carrots were used in studies to simplify procedures which have achieved some degree of acceptance through the years and to compare results obtained by different methods.

Conditions for separating and quantitatively determining fructose, glucose, and sucrose as the trimethylsilyl derivatives and using gas-liquid chromatography are being studied.

6. Technique for calcium determination in fruits and vegetables. The use of a reversed oxacetylene flame in conjunction with a "radiation" buffer mixed acid technique gave calcium results in excellent agreement with the permanganate titration procedure on a number of samples of fruits, vegetables, and composited diets. The new technique permits the use of smaller samples and allows calcium to be determined at lower levels than previously. A manuscript is in preparation.

B. Tables of Food Composition

1. B-vitamins and trace elements in foods. Compilation of data is well underway for the following B-vitamins--pantothenic acid, vitamin B₆ and vitamin B₁₂, and has been initiated for several trace elements. Data for these nutrients were not in the 1963 revision of Agriculture Handbook No. 8

"Composition of Foods...raw, processed, prepared." Special attention is being given to compiling data on cobalt, copper, manganese, molybdenum, selenium, and zinc.

2. Nutritive values of retail and household units of food. A table is being developed that will give nutritive values for many of the foods in Handbook No. 8 in terms of market units of the items as usually purchased and in terms of household measures of prepared foods. The data needed to prepare this supplement for the 1963 edition of the Handbook are being obtained through consultation with representatives of industry and of Consumer and Marketing Service as well as through observation of products offered for sale.

3. Special services. Research findings compiled from the world's literature on the nutritive value of foods continue to be in constant demand as background material for dealing with a wide variety of problems. Technical assistance was given in the formulation of a statement on nitrogen conversion factors for the Protein Committee of the Food and Agriculture Organization of the United Nations, in the development of policy and guidance for the Food for Peace Program, and in the development of educational materials on the so-called convenience foods for the use of dietitians in teaching diabetics. Information on the composition of specific foods or groups of foods was also given to research teams conducting dietary surveys, to welfare workers and to agencies of the Federal Government such as the Federal Trade Commission, the Food and Drug Administration, and the National Institutes of Health. Within USDA, information was provided for revising several tables in Statistical Bulletin No. 362, Conversion Factors and Weights and Measures for Agricultural Commodities and Their Products, issued in June 1965.

C. Nutritional Requirements

1. Preadolescents. Relatively low levels of dietary protein and relatively high levels of unsaturated fatty acids had little or no effect upon the serum lipids of 12 preadolescent girls maintained on all-vegetable diets under the Southern Regional Project S-28. For these girls (7-9 years of age), serum lipid components were essentially the same with all-vegetable diets as with their usual mixed diets containing animal protein when the vegetable diets supplied 40 gm protein per day; when the vegetable diet supplied 22 gm protein per day, serum cholesterol and phospholipid levels remained the same but glycerides increased, possibly because the diets lower in protein contained more sugar. A manuscript presenting these results has been accepted for publication by the Journal of the American Dietetic Association.

2. Adolescents. Work is continuing under contract on a study of adolescent girls at Andrews University, Berrien Springs, Michigan. To provide information which can be used in determining the nutritional requirements of girls in this age group, the metabolic response of 16 girls, 16-19 years of age, to a controlled ovo-lacto-vegetarian type diet is being measured. Parameters on which data will be provided for each girl include nitrogen and mineral balances, intake and output of fat, blood serum lipid components (total cholesterol, total fatty acids, phospholipids, and glycerides), and blood serum riboflavin. Data reported on the first seven girls studied indicate that while they were on the controlled diet all seven girls were in positive nitrogen balance and that they digested 97% of the dietary fat.

D. Diet and Fat Metabolism (PL 480 Research)

Among the many factors that are known to affect fat metabolism are genetics, age, and other physiological and environmental including numerous dietary factors. In one PL 480 project in India, the effect of diet on hormone regulation of body synthesis and mobilization of fat is being studied with rats. One group of animals is receiving a fat-free laboratory diet, and others are receiving protein and fat combinations characteristic of three population diets in North, South, and Central India.

In normal animals, the North India combination of 20 percent animal protein (casein) plus 20 percent butterfat caused significant rise in serum cholesterol. The South India combination of legumes (vegetable protein about 10 percent) and 10 percent coconut oil caused high initial serum cholesterol which in 30 days fell to levels below those on the stock ration. The South India combination of another vegetable protein and 10 percent sesame oil gave the lowest serum lipid levels of all. Rats on fat-free diets of 18 percent casein and 64 percent cornstarch and 12 percent sugar had serum cholesterol significantly above animals on the stock ration or on any of the population type of diets. Maximum synthesis of body fat occurred also on the fat-free diet. Irrespective of the diet used, removal of the thyroid gland led to higher serum cholesterol but it was most exaggerated on the North India combination. Administration of thyroid hormone tended to reverse the effect on all diets. Removal of adrenal glands depressed lipid metabolism but the effect was only partially corrected by corticosteroids, one hormone produced by the adrenals.

E. Food Consumption and Diet Appraisal

1. 1965 nationwide survey. A nationwide survey designed to provide information on the food consumption and dietary levels of people in the United States is now underway. Data on the kinds and quantities of food used during one week were collected under contract from more than 7,500 representative U.S. households between April 7 and July 3. Similar data

will be obtained from 2,500 households each in the summer and fall of 1965 and the winter of 1966. Information on the food eaten both at home and away from home during one day was provided by 13,000 individuals who were members of the families providing information on household food consumption during the spring of 1965. The study was designed to provide data for the four Census regions for farm, rural nonfarm, and urban populations for the year as a whole and for the four seasons.

Detailed tabulation plans have been drawn up that will provide for a series of volumes on the household data obtained in the spring of 1965 similar to those published for the 1955 survey. Other tabulation plans will provide information on (1) the 12-month period April 1965-March 1966 and for the four seasons, (2) the relationship between the money value of household food and its dietary adequacy, and (3) the intake of both food and nutrients of individuals by age and sex.

2. Effects of food distribution programs on diets of needy families.

Analyses of data from studies in Detroit, Michigan, and Fayette County, Pennsylvania, conducted to obtain information on the effectiveness of the Food Donation and Food Stamp Programs showed the following. (1) Many of the families participating in the Food Donation Program failed to participate in the Food Stamp Program when it replaced the Donation Program. The families who did participate in the Food Stamp Program were usually those of younger homemakers with more formal education, more young children, and lower incomes for family size. (2) Calcium and ascorbic acid were the nutrients which increased most when the Food Stamp Program replaced the Food Donation Program. They were also the nutrients in which diets were most limited (according to the National Research Council allowances) under both the Food Stamp Program and the Food Donation Program. (3) The overall quality of diets was better under the Food Stamp Program than under the Food Donation Program. (4) Under the Food Stamp Program participants received coupons which would purchase food worth considerably more in money than the foods received under the Food Donation Program--approximately 135 percent more in Detroit and 65 percent more in rural Fayette County. They were also able to make their own selections.

A study of families participating in the Food Donation Program in Baltimore showed that little or no dietary improvement occurred when the number of donated foods was increased from five to eight. Families cut back on their food purchases, apparently using the funds thus made available for other needs.

3. Food consumption of the rural population in Spain (PL 480 Research). A 1964 survey of the food consumption of the rural population in Spain, conducted by the Spanish Ministry of Commerce under the cooperative sponsorship of the Economic Research Service and the Agricultural Research Service, using PL 480 funds, showed the percentage of income spent for food was

much higher than in the U.S. However, the nutritive content of the diet was considerably lower than that of rural families of the U.S. For example, the average amount of calcium in the diet was about 0.5 g. per person per day compared to 1.2 g. in the diets of rural families in the U.S. in 1955. The percentage of calories from fat was 31 percent compared to 41 percent in the diets of rural families in the U.S. Although a wide variety of foods was used, a large share of the diet was supplied by bread, potatoes, dried beans, milk, olive oil, and wine. Tabulation of data from a second survey conducted in the early months of 1965 is in progress.

4. Nutritive value of national food supply. The revision of estimates of the food energy, protein, fat, carbohydrate, calcium, phosphorus, iron, vitamin A, thiamine, riboflavin, niacin, and ascorbic acid content of the per capita food supply from 1909 to the present has been completed. The revised figures incorporate newest estimates of per capita food consumption developed by the Economic Research Service, revised food composition data from Agriculture Handbook No. 8, and new information on the nutrients added to foods by enrichment and fortification.

The revised estimates and tables showing the contribution of major food groups to the total supply of each nutrient for selected years were published as Chapter 5 of Statistical Bulletin No. 364, "U. S. Food Consumption--Sources of Data and Trends," Economic Research Service, June 1965.

The estimates for nutrients together with the per capita food quantities on which they are based are extremely useful in studying dietary trends. For example, in 1909-13, potatoes provided 31 percent of the total ascorbic acid in the food supply. In 1963, the total ascorbic acid in the food supply was about the same as in 1909-13 but with per capita potato consumption down to about one-half of the earlier level, potatoes contributed only about 20 percent of the total. Increased amounts of ascorbic acid from fruits offset the decreased contribution from potatoes.

5. Household practices in home freezer management. Field work has been completed for the study of management practices of owners of home freezers. The information was obtained from 200 urban families in Fort Wayne, Indiana, and 200 farm families in the surrounding area. Plans made for tabulating the data will make it possible to describe for groups of families of homogeneous economic characteristics, the types of freezers owned, values attributed to freezer ownership, length of time foods are stored in freezers, and other freezer management practices.

6. Support for food and nutrition programs. The compiling and interpreting of research-based information on nutrition for application to problems of food selection and food use is continuing. The information so developed serves as a basis for assistance to many groups both within and outside

the Department. For example, technical advice and guidance were given during the year to the School Lunch Division, Consumer and Marketing Service, in revision of two publications designed to help improve the nutritional quality of school lunches. Also assistance was given to the Office of Economic Opportunity in the preparation of "Nutrition Guidelines" for the Project Head Start Centers Feeding Program.

Publication of Nutrition Program News and participation in the Interagency Committee on Nutrition Education, for which CFE furnishes the secretariat, are continuing as a means of coordinating and strengthening nutrition programs in general. A noteworthy accomplishment was the development by the Committee of four basic nutrition concepts to be used as guidelines for program planning and curricular development in nutrition education.

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CITRUS AND SUBTROPICAL FRUIT

Southern Utilization Research and Development Division, ARS

Problem. The citrus and subtropical fruit production of the Southern

Region is an expanding industry with the need for the development of better, as well as new-type consumer products, and for the improvement of present or invention of new processing procedures and machinery. These advances are required to regularly utilize the currently large production, particularly of oranges and grapefruit, and the anticipated higher production of these fruits, to the economic advantage of the growers and consumers. Basic research is needed to lay the groundwork for these advances. This research is needed, for example, on the composition and physical nature of essential oils, flavonoids, including bitter constituents, constituents responsible for oxidized off-flavors, carotenoids, and the like, which determine many of the sensory characteristics, and which affect product quality and stability. Other problems whose solutions are dependent upon the availability of more detailed compositional and physical data are: cloud stability, gelation, discoloration, fermentation, and the like. Increased production of citrus has stimulated the development of new products but many of these are urgently in need of improvement which will depend in part upon advances in basic research. New products are needed to attract new markets and also to reduce packaging and shipping costs. Research is needed to improve frozen citrus concentrates as processing procedures change, to develop better high density concentrate products, citrus powders, chilled juice and section products, pulp-fortified products, and to develop new or improved canned products which have a natural fruit flavor. Research is especially needed on grapefruit to develop practical methods for reducing the bitterness and harshness of juice products and to increase the use of grapefruit juice base in mixed fruit juice blends, drinks, concentrates and the like. Along with progress on product development there is a serious need to improve the actual processing procedures, processing equipment, and packaging operations and materials, to obtain and maintain the most desirable fruit characteristics particularly for citrus powders.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, food technologists, and a chemical engineer engaged in both basic and applied utilization research studies on citrus and subtropical fruits of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of citrus and subtropical fruits, and their products and by-products is conducted at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas and Winter Haven, Florida. This information provides the necessary basis for efficient research in developing new and improved food

products and processing technology. At the Weslaco Laboratory the program includes investigations of the influence of seasonal changes of carotenoid and flavonoid constituents which directly or indirectly affect color and flavor of processed products from Texas colored grapefruit, as a basis for improvement of processing characteristics of and products from these grapefruit. The Texas Agricultural Experiment Station (substation 15, Weslaco), Citrus Rootstock Investigations Laboratory (CR, ARS, Weslaco), the Texas College of Arts and Industries, and Rio Farms, Inc. (Edcouch) are providing grapefruit of known history and conducting, or cooperating in conducting, on-the-tree tests. Additional research on chemical composition and physical properties is carried out under a contract at the University of Oklahoma Research Institute, Norman, Oklahoma, on investigations of the effect of maturity of grapefruit on total flavonoid, naringin, and poncirus; and on the chemistry and nature of naringin and naringin-derived compounds to provide a scientific basis for the control of bitterness in processed grapefruit products. At the Winter Haven Laboratory the program includes: research to identify recently isolated flavones and other neutral orange peel constituents and evaluate their relation to bitterness and harshness in orange products; investigations of the composition of essential oils in citrus products, particularly orange, to provide a basis for improvement in quality and uniformity of citrus products; a study of off-flavor development in processed citrus juice in relation to the lipid composition of the suspended matter; and research to explore means for minimizing or blocking the formation of bitter components in grapefruit, a key step in developing processed grapefruit products of greater attractiveness to the consumer. Close consultation is maintained with the Florida Agricultural Experiment Station (Citrus Experiment Station, Lake Alfred; Citrus Research Investigations (CR, ARS, Orlando); Florida Citrus Mutual (Lakeland); and the citrus processing industry.

Research to develop new and improved food products is carried out at the U. S. Fruit and Vegetable Products Laboratories at Weslaco, Texas, and Winter Haven, Florida. At the Weslaco Laboratory the major applied effort is to develop products which will make greater and more efficient use of grapefruit. This research is being carried out in part in cooperation with several state and private organizations. The cooperators provide fruit or raw materials, such as pulp and juice, of known history. Processing plant facilities are available from the Texsun Citrus Corporation (Weslaco) and Rio-Vac, Inc. (Harlingen). Formal agreements exist with the Texas Agricultural Experiment Station (College Station and Weslaco), with Texsun Citrus Corporation (Weslaco) and with Rio Farms, Inc. (Edcouch). Informal cooperation is maintained with Texas Citrus Mutual, Inc. (Weslaco), Texas Canners Association (Weslaco) and such other organizations as are found necessary for the procurement and processing of fruit. At the Winter Haven Laboratory research is in progress to develop high quality, "instant" citrus powders by new and improved processing technology as described below.

In the field of new and improved processing technology, research is being carried out at the U. S. Fruit and Vegetable Products Laboratory, Winter

Haven, Florida, to determine how the "foam-mat" type of air-drying can be applied for the preparation of dried citrus products of optimum flavor and stability. Foam-mat drying of orange juices, and grapefruit juices, is currently being studied. This research is conducted in cooperation with the Western Utilization Research and Development Division (ARS) and the Florida Citrus Commission under a formal memorandum of understanding. Additional research on new and improved processing technology is being carried out under contract at the Citrus Experiment Station, University of Florida, Lake Alfred, Florida, on the development of a practical and efficient pilot plant scale process for the production of enzymatically debittered grapefruit juice and products with improved flavor, product stability and storage characteristics.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 20.6 professional man-years. Of this total 13.2 is devoted to chemical composition and physical properties, and 7.4 to new and improved processing technology. The contract research involves an additional 1.9 man-years, 1.4 being on chemical composition and physical properties, and 0.5 being on new and improved processing technology.

The following lines of work were terminated during the year: (1) Investigation of the chemical and physical nature of components of cloud of orange juice, to provide better understanding and control of factors affecting stability of orange juice products (under Chemical Composition and Physical Properties); and (2) Utilization of natural and debittered grapefruit juice and puree as bases for the development of improved fruit juice blends, drinks, and concentrates (under New and Improved Food Products).

PROGRAM OF STATE EXPERIMENT STATIONS

State stations engage in both basic and applied research on the utilization of citrus and subtropical fruits with the objective of expanding markets and increasing utilization of these crops. Citrus, oranges, grapefruit and tangerines are held in special environmental control chambers and the various combinations of temperature, humidity and airflow are studied to determine subsequent effects on quality. Efforts to reduce decay during storage and transit lead to research on the basic physical, biochemical and physiological changes which occur during handling and marketing. Factors influencing quality of mature avocado fruits are evaluated by study of the respiratory rate, various physiological disturbances, ripening rate and external and internal quality of fruits. Non-destructive physical measurements of quality are sought.

Product research and development includes study of processes for canning grapefruit sections. Special attention is given to problems of texture, structure, flavor and color. The characteristics of commercial frozen Florida orange concentrate and superconcentrate are determined at intervals and used to establish characteristics of these products. Characteristics of canned and frozen concentrated juices are studied initially and after storage

at elevated temperatures. Efforts to extract, separate, identify, and determine quantitatively each of the volatile components responsible for the natural flavors and occasional off-flavors in citrus fruits, citrus oils and processed citrus products continue. The determination of the relationship of all components to the total flavor and aroma presents numerous unsolved problems.

Certain properties of avocado polygalacturonase and papaya pectinesterase are being studied. In addition, the enzymes of the fig latex are being isolated and characterized as to molecular weight, activity and amino acid composition.

Work with subtropical crops such as guava, mango, soursop, banana, pineapple, coffee and plantain involves development of processes for preservation of the delicate and characteristic flavor of these fruits. Production of freeze-dried products of high quality and storage life is under study. Products such as banana puree, fried snack items, fruit powders, candied items, and nectars are receiving attention.

The Hawaii and Puerto Rico stations conduct research to strengthen their coffee industries. These studies include research on the microbiology of the coffee fermentation process, on drying coffee and on the quality and acceptability of the final product. Basic equilibrium moisture content data for parchment and green coffee are being developed to guide design of an experimental system which uses solar energy for drying coffee.

Research designed to recover or make useful products from citrus and pineapple wastes is in progress. Other work is directed to conversion of citrus terpenes to useful chemicals and to use of isolated cultures from natural sources to produce glycerol and glycols from citrus wastes by fermentation. Feasibility studies on the preparation of livestock feeds from farm product and distillery, cannery and brewery wastes continue with materials selected for study being pineapple, citrus and pigeon pea cannery wastes, spent grains and blackstrap molasses.

The research effort devoted to citrus and subtropical fruit utilization research is about 19.6 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Chemical and Physical Properties of Removing Constituents of Florida Citrus and Subtropical Fruit Products. In a new project continuing basic work on the composition of citrus oils to improve the quality of citrus products, nootkatone, an important flavoring constituent of grapefruit, was synthesized from valencene, a major sesquiterpene of orange oil, in a one-step oxidation using t-butylchromate. This accomplishment provides an additional source for nootkatone as a flavoring material.

Rapid analysis of hydrocarbons by use of the Time-of-Flight Mass Spectrometer has facilitated identification of the constituents of the essential oils in citrus products. The process, which offers semiquantitative analysis, can be completed in about 90 minutes and requires only 1-2 ml. of oil. Thirteen citrus oils investigated include processed oil, juice oil, condensate oil, and oils of orange (several varieties), grapefruit, tangerine, lemon, and lime. Fifteen sesquiterpenes including α - and Δ -elemene have been identified in citrus oils. A high concentration of valencene, the principal constituent in orange juice oil, was found in grapefruit juice oil. The procedure for isolating alcohols from citrus oils was simplified. Nineteen alcohols have been found in orange cold-pressed oils, 10 of which had not been previously reported in orange oil--in fact, four of these 10 had never been reported in any natural product. Seventeen alcohols in grapefruit oil have been identified as c - and t -linalool oxide, linalool, actanol, c - and t -2,8-p-menthadiene-1-ol, nonanol, α -terpineol, decanol, citronellol, geraniol, c - and t -carveol, undecanol, dodecanol, elemol, and 8-p-menthene-1,2-diol. Composition studies will continue to include other oxygenated materials in the oil. (S3 2-48).

2. Investigation of the Bitter Principle and Flavonoids in Citrus Products. In another new project that continues work already begun, the monitoring study of peel juices for the 1963-64 season has been completed; combined with the 1962-63 results, it provides information on variation in peel juice bitterness for a normal season and for one in which a freeze occurred. Much of the bitterness resides in the neutral fraction of the benzene extract, an analysis of which has accounted for 80% of the constituents. The structure of the unknown flavone in the neutral fraction of orange peel juice extract was identified: it is tetramethoxy scutellarein (5,6,7,4'tetramethoxyflavone). Although this compound has been synthesized and prepared as a derivative of related flavones, it has never before been found in natural products. A recently developed method of analysis by thin-layer chromatography has permitted determination of flavones constituting 60 to 90% of seven neutral fractions of peel juice extract. Their ranges are: tangeretin, 2.1-14.8%; tetra-O-methylscutellarein, 6.1-10.3%; heptamethoxyflavone, 7.6-11.0%; nobiletin, 20.6-26.0; and sinensetin, 19.2-28.2%. A new compound was also detected, and efforts to isolate it are being continued. The analytical data suggest that there is a correlation between tangeretin content and bitterness, but taste tests have not yet verified that this is the most important bitter constituent. Preliminary results utilizing a method of analysis developed by Australian scientists suggest that some bitter Florida orange concentrates contain limonin, which is a lactone and therefore not expected to occur in a neutral fraction and never before demonstrated in Florida orange juice. However, if tangeretin and limonin do prove to be important bitter principles, they can be estimated, respectively, by the new methods of analysis developed by Division and Australian scientists. (S3 2-47).

Significant progress has been made by the contractor (University of Oklahoma Research Institute) in determining the effect of grapefruit maturity on total flavonoids and on naringin and poncirin. A second naringin (naringin 2) that may be the nonbitter naringenin 7-rutinoside has been isolated. In midseason

juice, the ratio of naringin 1 (bitter) to naringin 2 (possibly nonbitter) was 3 to 1; in late-season juice, this ratio was 2 to 1. Total naringin value of late season juice was approximately 75% that of midseason juice, the decrease being almost entirely in the amount of naringin 1. If it can be demonstrated conclusively that naringin in grapefruit may exist in both bitter and nonbitter forms and that the former decreases as the season progresses, the basic knowledge will be provided to aid in identifying factors affecting bitterness and to improve quality control in processing of grapefruit. A recently developed chromatographic-fluorometric method for the determination of naringin, naringenin rutinoside, and related flavone glycosides in grapefruit juice permits more accurate assay of bitterness. Approximate R_f values for the various compounds separated on thin-layer chromatographic plates were: isosakuranetin rutinoside, 0.67; poncirus, 0.60; hesperidin, 0.50; neohesperidin, 0.43; naringenin rutinoside, 0.37; and naringin, 0.30. The chromatographic-fluorometric method affords a tool for following the degree of bitterness as it is affected by maturity, breeding, and environmental factors, and also provides the basis for developing simpler methods of processing control. Before the contract terminates, the flavonoids of Texas Red Grapefruit harvested at monthly intervals will be differentiated. (S3 2-39(C)(Rev.)).

During the related investigation on bitterness and harshness in Florida grapefruit products, nine coumarins were isolated from grapefruit: four were identified as coumarins previously reported in grapefruit; three as coumarins not previously reported in grapefruit; and the remaining two have not been completely identified, although one was classified as a coumarin and the other as a psoralen. None of the coumarins tasted are bitter. Research on bitterness of grapefruit is continuing under a new project, S3 2-49. (S3 2-42).

The new project on bitterness in grapefruit products is directed toward minimizing the biogenesis of bitter constituents through enzymatic inhibition, thus obviating the need for removing them by expensive processing. The use of radioisotopes will afford a technique selective enough to explore particular metabolic pathways to the exclusion of others, and sensitive enough to detect and identify minute quantities of compounds. The first step will be to establish the immediate precursors to naringin and poncirus. For grapefruit, this step will be investigated by use of radioisotopically labeled acetate and cinnamic acid, shown in other plants to be precursors to the C-15 nucleus of flavonoids. To date, only nonradioactive materials have been used, while steps preparatory to use of radioactive materials have been taken. Since several required radioactive compounds are not commercially available, synthetic procedures applicable to radiosyntheses were investigated with non-radioactive compounds. Thin-layer chromatography and electrophoresis were explored as means of isolating and identifying compounds related to bitterness. A highly purified sample of naringin was prepared and a standard ultraviolet absorption curve constructed to be used in the quantitative determination of bitterness. (S3 2-49).

3. Factors Affecting the Physical Characteristics of Processed Citrus Products. Analyses of the cloud of orange juice are now complete and the project has been discontinued. Juice was sampled from the three major varieties of oranges, and the study included early and midseason ranges, representative of normal and freezing seasons. In addition, the composition of albedo, rag, pulp, and juice from two samples of Valencia oranges was compared with cloud components recovered by centrifugation from commercially extracted juices. Neither fruit variety nor freeze damage to fruit on the tree produces major differences in the composition of cloud in orange juice. Also, excessive maceration of structural tissue during extraction and finishing does not contribute materially to cloud; nor does avoidance of this practice reduce cloud. The previously reported theory that natural cloud comes from the juice rather than from mechanical disintegration of structural tissue was thus confirmed: there was a high lipid content of fine cloud recovered by centrifugation, and high levels of nitrogen and phosphorus in the solvent-insoluble fractions of fine cloud, whereas there were low amounts of these constituents in albedo, rag, and pulp.

A method for more accurate, precise, and rapid determination of recoverable oil in citrus juices was developed. The complete determination requires only 25 ml of juice and 10 minutes, in contrast to 2 liters of sample and about one and a half hours for the official method. All variable conditions of the method have been studied, there remaining only its application to samples from the full range of commercial citrus varieties. Since recoverable oil content is an important factor in quality grading of citrus juice products, this method should gain acceptance in industry: the Florida Canners' Association has recommended that it be brought to the attention of the Institute of Food Technologists. (S3 2-38(Rev.)).

4. Basic Investigations of Carotenoids in Grapefruit. Verification of the biochemical mechanisms involved in the biosynthesis of carotenoids in colored grapefruit and other fruits and vegetables would facilitate improvement of processing. In recent investigations of the relationship of carotenoids to color, flavor, and processing reactions, tomatoes were used as a model system because they synthesize carotenoids much more rapidly than do grapefruit. To determine the concentration of carotenoids at different stages of maturity, spring and fall Homestead tomatoes were analyzed according to the standards listed in Tomato Color Classification, USDA, 1961. Of the carotenoid pigments determined, only alpha- and beta-carotene were found in the mature green stage; these two, as well as zeta- and gamma-carotene, phytofluene, and lycopene, were found in the breaker stage; phytoene was not found until the turning stage. Since the concentrations of these carotenes decrease or increase during different stages of maturity, it may be possible to use their ratios as a measure of maturity of tomatoes. Also of importance is the evidence that the concentration of pro-vitamin A is highest in the light red stage of maturity. This work supports the theory that different carotenes are made via different metabolic pathways. In addition to providing information on the general problems of carotenogenesis, this study on the concentration and ratios of carotenes should prove useful to breeders of Homestead

tomatoes in selecting lines capable of maximum color development and to processors as a precise measure of maturity. In another phase of this work, an extract of parsley was prepared to isolate and identify the nonsaponifiable material that has chromatographic properties similar to the carotenes. Eleven different compounds were found by thin-layer chromatography, whereas over 20 compounds were found in a sample sent out for analysis by gas chromatography. Additional work will be conducted with respect to nonsaponifiable material. Preliminary work, to be expanded under a new project, has shown that the carotene content of grapefruit treated with paraffinic oil sprays is higher than that in unsprayed fruit. This type of treatment may offer a way to augment the carotene and lycopene in grapefruit and to delay loss of color during the harvest season. (S3 2-34(Rev.)).

B. New and Improved Food Products

1. Development of New Grapefruit Based Beverages. Good progress has been made in the investigation of the flavonoids in Texas grapefruit, the control of bitterness in grapefruit products, and the development of debittered grapefruit juice that can be used in processed products. Those advances, together with related research in other Federal laboratories, offer promise of imminent development of successful beverages. Radio-carbon studies have confirmed the hypothesis that flavonoids develop primarily during early growth of the grapefruit. Fruit harvested from trees exposed at monthly intervals, beginning with the period of spring bloom, to carbon dioxide tagged with carbon-14 were analyzed for the tagged flavonoids to determine the sequence and time of their development in the maturing fruit. Full-grown fruit from trees treated in November 1963 had no detectable activity in the flavonoids. Prunin is one of the flavonones found to be present in young fruit. Continuing work on the tagged fruit, coupled with the fluorometric analysis of flavonoids recently developed under another project (S3 2-39(C) (Rev.)) should provide valuable information on the accumulation and modification of bitterness during the season and its effect on the processed product. New analytical methods that have aided in the study of the flavonoid bitterness of grapefruit include a simple method for extracting flavonoids from citrus juice and a chromatographic solvent system for excellent separation of flavonoids.

Additional work has been done on debittering grapefruit juice by enzymatic treatment or by resins. Enzymatic hydrolysis with naringinase C-100 of flavonoids present in grapefruit showed the enzyme to be nonspecific; consequently, use of this enzyme may have an undetermined influence on juice quality. Since some of the polyamide resins used in the other type of debittering process irreversibly absorb some of the minor flavonoids, their repeated use may be limited.

Several formulations have been developed for concentrated fruit juice punches in which natural or partially debittered grapefruit juice is the major juice constituent. Tasters rated punches prepared from half-debittered grapefruit juice preferable to those prepared from normal juice or from completely

debittered juice. Punches flavored with raspberry or strawberry were judged best and warrant consumer acceptance studies. (S3 2-40).

C. New and Improved Processing Technology

1. Application of Foam-Mat Drying to Citrus. In cooperation with WU and the Florida Citrus Commission, the research to improve the storage stability and quality of foam-mat citrus powders is continuing. Reconstitution has been improved by vacuum packing, repackaging in CO₂, or packing under CO₂ positive pressure. Such packing obviates reconstitution difficulties previously associated with use of monoglyceride foaming agents. A good foaming procedure has been developed for the recently installed Oakes mixer, and the new crater dryer can now be used to routinely produce orange and grapefruit powders having lower moisture content achieved at lower temperatures. The foaming procedure has now been modified so that less than 0.5% additive on a solids basis is required. Freeze-dried orange and grapefruit powders have been prepared for use as flavor additives, and their use could make foam-mat powders equivalent in quality to frozen concentrates. Orange powders have been stored at 60° F. or lower for over 39 weeks without detectable change in flavor. A compound that was chromatographically separated from off-flavor powders but not from control powders or concentrate has been isolated and identified as 5-hydroxymethylfurfural; a routine method of testing for its presence shows promise as a quality control process. Two machinery companies and many food and packaging companies have expressed interest in this process and in plans for consumer testing. Plans include continued study of the relation of time and temperature of drying to product quality and to storage characteristics, a continued investigation of the use of freeze-dried powders, and organoleptic evaluation of various combinations of foam-mat and freeze-dried powders. (S3 2-43).

Under other cooperative research with WU and the Florida Citrus Commission, foam-mat dried grapefruit powders having commercially acceptable storage stability have been developed. At 70° F. or less, they would last for eight months to a year without detectable changes and for much longer before consumer acceptance would be seriously reduced. Either cans or plastic-laminated foil pouches could be used for commercial distribution. Improved foaming procedures permit drying on the crater dryer to less than 1% moisture content and enable preparation of very satisfactory foam by use of Methocel alone in concentrations of less than 0.5% total additive on a solids basis. Drying at lower temperatures and reduction in amount of additive enhances the fresh-juice quality of reconstituted powders. Consumer acceptance tests are being planned in cooperation with the Florida Citrus Commission, technical assistance has been given to one company using an adaptation of the foam-mat process, and many food and packaging companies have expressed interest in the process and in the plans for testing consumer acceptance. (S3 2-41).

2. Process for Enzymatically Debittering Grapefruit Products. A new contract has been negotiated with the Florida Agricultural Experiment Station to develop a practical and efficient pilot-plant process for the production

of debittered grapefruit juice and grapefruit products by means of commercially available enzymes. The project is designed to improve palatability and acceptance, increase stability and quality retention during storage, and provide engineering and cost data applicable to commercial production. The preliminary experiments have been designed, the processing equipment readied, and a planning conference held to formulate a work schedule. However, difficulty experienced in obtaining a pound of commercial naringinase enzyme obviated its use for pilot plant studies on early (bitter) grapefruit and has necessitated postponement of work until a new crop of grapefruit becomes available in October 1965. In the meantime, cans of commercial grapefruit sections were shown to vary widely in naringin content. In a series of analyses to determine how rapidly equilibrium diffusion occurs in canned grapefruit sections, naringin values during storage as long as three weeks did not increase over the initial analysis made six hours after canning. A new laboratory finisher which does not apply pressure to the pulp during extraction is being secured for use in the research; the effect of this new principle of extraction will be investigated. (S3 2-46(C)).

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CITRUS AND SUBTROPICAL FRUIT

Western Utilization Research and Development Division, ARS

Problem. The economic stability of the citrus and subtropical fruit industries in the Western Region is dependent upon effective utilization of fruit that cannot be accommodated on the fresh fruit market. The utilization of surplus or wholesome but blemished fruit provides the margin necessary to assure adequate returns to the farmer and continued development of stable markets. Ineffective utilization of products and continuously increasing processing costs are resulting in decreased returns to the growers. The California-Arizona grapefruit industry is encountering difficulty in disposing of both fresh fruit and processed grapefruit products. The pineapple and subtropical fruit industry in Hawaii must find practical methods for processing its products for export in order to prevent the accumulation of burdensome surpluses. The navel orange industry in California is hampered by the unavailability of satisfactory processes for the utilization of navel oranges. Juice extracted from early fruit, and during some seasons from almost all of the navel oranges, contains substances that impart an intolerable bitter flavor to juice products after mild heat-processing or after standing at ambient temperature for a short time. Large new plantings of navel oranges may be expected to aggravate the utilization problem. Deterioration of the flavor and color of these and other processed citrus and subtropical fruit products imposes severe limitations upon the economic stability of the industry.

Information is needed on the chemical composition of citrus and subtropical fruits and their products and byproducts as a basis for the development or application of new and improved methods of processing; and for the production of new and improved food and industrial products and pharmaceuticals. Special attention needs to be given to the nature of the chemical changes involved during pre-treatment, processing and handling which lead to the formation of off-flavors, -colors, and -odors in processed products.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a concentrated program of fundamental research on citrus and subtropical fruit and its application to industry problems is conducted at the Division headquarters at Albany, California; at the Fruit and Vegetable Chemistry Laboratory in Pasadena, California; at the University of Hawaii, Honolulu; by contracts at Pasadena, California and Tucson, Arizona; and, under a P.L. 480 grant, in Bogota, Colombia. Investigations are conducted on the composition of citrus essential oils, flavonoid compounds and other citrus constituents that are related to off-flavors and darkening of citrus products, the natural flavor components of oranges, enzyme systems that are involved in the appearance and disappearance of constituents and structures of plant tissues,

constituents of dates that affect the quality and stability of products, and the application of findings of such research to the development of new and improved citrus, tropical, and subtropical fruit products.

The Federal program of research in this area totals 19.4 professional man-years, including contract research equivalent to about 1.6 professional man-years per year and two scientists whose salary is provided under Memorandum of Understanding by the Lemon Products Technical Committee. Of the total, 12.2 are assigned to investigations on chemical composition and physical properties and 7.2 on new and improved food products and processing technology. In addition, the Division supervises two research projects supported by P.L. 480 grants.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 221.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Citrus Composition. Citrus components are being isolated and identified to provide foundation knowledge that will help improve citrus products and processes. Over the past several years, the major polyphenolic compounds of citrus fruits have been isolated and identified, and a number of previously unreported compounds have been discovered. Naringin had been thought to be the only important polyphenol of grapefruit. Now we have isolated and identified six other major polyphenols from the edible portion (endocarp) of grapefruit by enzymic hydrolysis. These findings are of major significance not only to citrus processors but also to geneticists, botanists, and plant physiologists, since they shed light on the distribution patterns in various citrus varieties.

The chemical structure of nootkatone, a sesquiterpene ketone discovered in grapefruit and other citrus oils last year, has been elucidated. The structure satisfied all the chemical spectral evidence developed, including elemental composition and IR, UV, and NMR spectra. Other oxygenated sesquiterpenes appear in lemon oil but in lesser amounts.

Research on lemon oil and lemon juice is supported in part by the Lemon Products Technical Committee. Data on lemon juice composition collected over five seasons were subjected to multiple regression analysis; the equations obtained are useful for predicting the expected levels of citric acid in unaltered lemon juice. Sterol, carotenoid, and citric acid values in 26 samples of commercial lemon concentrate were determined. The average values of these components in fresh coastal and fresh desert lemons were not significantly different from the average values of their concentrates.

Preliminary results indicate that acidity decreases in lemons during periods of low humidity (such as hot dry winds), but it increases to its previous value when the humidity is increased. A 5% increase in citric acid content of lemons was obtained by increasing the humidity around a tree with an overhead water spray. This new information, along with the multiple correlation of analytical data, should lead to a more precise definition of authentic lemon juice in terms of its citric acid content.

2. Bitter Constituents of Citrus. Extensive work has been conducted on the flavonoids and limonoids, two types of compounds that are natural constituents of oranges and grapefruit and that can cause bitterness in these fruits. Desoxylimonin, known previously only as a synthetic derivative of limonin (a bitter principle of navel oranges) was isolated from grapefruit seeds and identified. It was found to be tasteless. If a mechanism could be found that would convert limonin to desoxylimonin, it would suppress bitterness in navel orange products.

In addition to limonin, nomilin and obacunone are compounds known to cause bitterness in navel orange juice. Citrus processors need a simple, practical assay method for these three compounds so that lots of fruit high in bitterness can be diverted to nonfood uses. Contract research has been initiated at Stanford Research Institute, Menlo Park, California, to develop such analytical methods.

3. Fruit Flavor Components. We have greatly improved the resolution, capacity, and sensitivity of gas chromatographs in order to facilitate the study of hydrocarbons and oxygenated compounds found in citrus and deciduous fruit volatiles. The volatiles from single pieces of fruit can now be analyzed. Molecular weight and structural information can be obtained with microgram and even smaller quantities by direct coupling of gas chromatography columns to a fast-scan mass spectrometer.

Chemical studies emphasize methods for the recovery of volatile components of fruit juices. In volatiles from orange juice prepared so as to minimize or eliminate contributions of peel oil, 35 compounds have been identified. Ten of them are newly identified from this source; 7 others had been only tentatively identified in orange juice prior to this work. Aroma contribution of individual compounds is being evaluated by test panels.

Research on stabilization of flavor concentrates of tropical fruits is supported by a P.L. 480 grant to the Institute of Technological Investigations in Bogota, Colombia. Aromatic components have been solvent-extracted from the guava, fractionated by distillation, and analyzed by gas chromatography. A novel method of flavor extraction is being studied: Fruit pulp is layered with powdered sugar, which partially dries the pulp, and in the process the sugar is converted to syrup which contains appreciable amounts of volatile flavoring substance. Essence is then stripped from the syrup by distillation and concentrated. An essence concentrate that preserved the pleasant character of the fresh fruit was prepared from curuba pulp in this way.

4. Composition of Dates. Three polyphenolic acids related to enzymatic browning reactions in dates were isolated and their structures determined. Other organic acids are being identified. Of ether-soluble acids in immature dates, about 75% was malic acid. Phosphoric, citric, and galacturonic acids were present in uncombined form. Shikimic, glycolic, and galacturonic acids were in bound form and represented about 4%. The presence of bound shikimic acid and the absence of quinic acid suggest the absence, also, of quinic acid dehydrogenase enzyme activity. The unique presence of caffeoylshikimic acid suggests that a metabolic activity may be present in dates that is different from that in most common fruits, which contain significant amounts of quinic acid. Four flavans that were enzymic browning substrates were found in immature dates but not in mature dates. The disappearance of such compounds during maturation suggests that enzyme-catalyzed browning is partly responsible for the characteristic golden brown color of ripe dates.

5. Pharmacological Investigations of Citrus Products. The metabolism of caffeic acid depends upon micro-organisms in the gut rather than upon endogenous reactions within the animal body. This observation led us to initiate studies of metabolism *in vitro* that may lead to a more basic understanding of the metabolic fate in animals of minor phenolic constituents of citrus. Freshly voided animal feces were incubated with various substrates, such as the flavonoids and phenolic acids common in citrus fruits and other plant materials. Preliminary indications of the nature of the primary metabolic breakdown of quercetin were obtained. Identification of several bio-fermentative phenolics produced from flavonoid nuclei is in progress. Other common phenolic compounds such as dihydroxyphenylalanine, xanthurenic acid, D-catechin, phloroglucinol, and rhamnetin are now being investigated by this procedure.

B. New and Improved Food Products and Processing Technology

1. Citrus Products. Low-calorie sweeteners can be made by converting the flavonoids naringin and neohesperidin to their dihydrochalcones. Improved methods have been developed for the direct conversion of commercially available and relatively cheap naringin to the much more expensive neohesperidin and its dihydrochalcone. This direct conversion improves the outlook for the practical production of a food sweetener. Requests for samples and information on their preparation indicate a continuing commercial interest in this development.

Compositional studies of the carotenoid pigments of citrus fruits have revealed the presence of a red-orange pigment, citranaxanthin, which is the first known naturally-occurring carotenoid with a methyl ketone side chain. Citranaxanthin has provitamin A activity and good stability in vegetable oils, oil suspensions, and emulsions. It may have use as a food color.

Contract research was initiated at the University of Arizona to develop new food products from desert grapefruit, with particular emphasis on blends of grapefruit and other fruit juices, new diced and segmented grapefruit products, and grapefruit juice or puree for use as an ingredient in other food

products. Preference levels for sweetness, sourness, bitterness, and saltiness were evaluated, and an acceptable standard as compared with juice was developed (0.02% naringin, 0.1% acid as citric, and 13° Brix). A blend of 25% seedless grape juice and 75% grapefruit juice was prepared and filtered to give a clear product. It had excellent taste and eye appeal. Tests with firm, early-season peeled grapefruit indicated the possibility of adapting commercial equipment to the mechanical dicing of grapefruit. Microwave heat pasteurization of diced grapefruit in plastic pouches showed promise as a means of extending the shelf life of refrigerated grapefruit salad. Enzymic debittering of grapefruit juice with cellulase increased soluble solids content and gave higher yields of product with lower bitterness, better cloud, and fewer particles large enough to settle during storage of the product.

2. Tropical Fruit Products. In Hawaii, interest is growing in diversification of fruit products. Research on the technology of fruit processing and demonstrations of good practices at our field station in Honolulu are aiding this industry. Dehydrated banana products of satisfactory quality were prepared by air drying, freeze drying and drum drying, and the stability of the dried products was tested at three different storage temperatures. Two varieties of bananas have been tested for processing quality; the use of sulfur dioxide to prevent deterioration was included in the experiments. Juice and puree concentrates for remanufacture into jellies and preserves were prepared from guava, papaya, and passion fruit. Pectin-degrading enzymes had to be used to reduce the thickness of guava and papaya purees so they could be concentrated. Passion fruit puree did not require this pre-treatment. Starch-splitting enzymes were used to control the consistency of poi, which tends to thicken when held for a few days in markets. These preliminary experiments indicate the possibility of fairly precise control of the consistency of poi, which has a sizable market in Hawaii. The use of poi in baby food, particularly to avoid grain-flour allergies, may widen the market for this product.

3. Foam-mat Drying. In cooperation with the Southern Utilization Research Division at Winter Haven, Florida we conduct research on foam-mat drying of orange and other citrus products, and informal cooperation continues with industry on the commercial application of foam-mat drying, particularly in connection with the development of equipment. In-house activity during the past year has consisted largely of studying factors such as solids content, foam density, stabilizer level, foam temperature, and dryer temperature for drying various liquid foods. Berry purees foam-mat dried with sugar added retain excellent flavor and aroma. A non-caking foam-mat-dried edible molasses was prepared by bin drying in trays to 1% moisture content a product that had been foam-mat dried to about 2-1/2% moisture. Cranberry juice foam-mat dried with sugar added reconstitutes readily to a product with quality similar to that of cranberry juice available in domestic markets.

It has now become possible to foam-mat dry citrus to less than 1% moisture by using fine-bodied foams. This allows us to omit the expensive, awkward, and bulky in-package desiccant bag previously needed to avoid caking. Another

improvement relates to increasing the powder density. The powder can be converted to small flakes by squeezing it between warm steel rolls. In this way the bulk density may be raised from 0.3 to 0.8 gm. per ml. This now allows a manufacturer to put 70% more juice solids in a package by foam-mat drying than frozen juice concentrate.

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New and Improved Food Products and Processing Technology

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DECIDUOUS FRUIT AND TREE NUTS

Eastern Utilization Research and Development Division, ARS

Problem. Lack of knowledge of the nature and quantities of the various chemical constituents and enzyme systems present in fresh fruits, and of the changes these undergo during processing, is a limiting factor in research designed to develop new and improved products and processing techniques. Knowledge is required on the composition and physical structure of fruits and fruit products, with emphasis on substances responsible for color and flavor, vitamins, and other constituents important in determining consumer acceptance and nutritive value of the products. Composition should be studied in relation to variety, stage of maturity, and environmental conditions of growth; and to changes occurring between harvesting and processing, during processing, and in storage and distribution. Recently developed equipment and techniques have made it possible to isolate, separate, and identify constituents that could not have been handled previously. As basic information is developed, new processing techniques will be applied in the improvement of fruit products, and in more efficient utilization of by-products from fruit processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving chemists, biochemists, and chemical engineers engaged in both basic and applied research related to extending the use of fruits in the food processing industries. In the EU program apple products research, and investigations on the chemistry and cell structure of cherries are conducted at Wyndmoor, Pennsylvania. Development of rapidly-reconstitutable dehydrated fruit pieces is also underway at Wyndmoor. Contract research on peaches is in progress at Rutgers University, New Brunswick, on apple texture at the Maryland Agricultural Experiment Station, College Park, and research on the metabolism of red tart cherries was initiated recently at Temple University, Philadelphia.

The Federal (EU) scientific effort devoted to research in this area totals 10.3 professional man-years. Of this total, research on chemical composition and physical properties constitutes 3.7 p.m.-y., including 0.4 p.m.-y. of contract research on apple texture at the Maryland Station and 0.4 p.m.-y. at Temple. Research on new and improved food products amounts to 3.7 p.m.-y., and research on new and improved processing technology amounts to 2.9 p.m.-y., including 0.4 p.m.-y. of contract research on peach processing at Rutgers.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The States have a continuing and effective program of research on fruit processing and fruit products. Fruits possess unique flavor, color and nutritive qualities which make it desirable although difficult to preserve their unique qualities.

Fruit utilization research begins with evaluation of varieties and selections for processing quality as a service for breeding programs. In addition the relationship of other production and cultural practices to the quality and utilization of the finished products are determined. The biochemical changes associated with post-harvest storage and ripening are studies in an attempt to elucidate the metabolic reactions associated with ripening and to devise means of their control. Respiratory activity of fresh fruits is determined and used as an indication of package environment and to guide package selection. Increased use of mechanical harvesting equipment has been found to directly affect the quality of the fresh fruit and processed products.

Increased interest in pesticide residues on food products has led to the initiation of three regional projects. This regional research is centered around development and evaluation of procedures for reduction or elimination of residues in processed foods. Fruits and fruit products are among the commodities being studied.

The chemical composition and physical properties of certain fruits are being investigated in detail. The color and pigments of fruits are of special interest. Basic research on identification of the polyphenols of fruits and their role in enzymatic browning is continuing. The ultimate texture and reconstitution properties of fruit products are related to the properties of the pectic substances contained in the fruit initially. For example, the polysaccharides of the cell wall and other tissues are under investigation because these compounds are so important to texture of the products. Ethylene metabolism and its role in fruit ripening is under study.

The chemistry of flavor continues to advance with improvements in gas chromatographic procedures. Compounds which have the characteristic properties of fruit flavors are isolated and identified by this technique. Considerable effort is devoted to determining their significance in the flavor response to specific fruit flavors. These findings are correlated with taste evaluations and, through this process, some insight into the development of undesirable flavor is gained.

As previously indicated, study of enzyme mechanisms and properties constitute an important and continuing phase of basic research on fruits. More applied phases of investigation deal with such problems as development of off-flavors in frozen fruit products, enzymatic browning of fresh tissue and methods for control of this form of browning.

Investigations of the ecology, taxonomy and physiology of yeast, molds, and bacteria involved in food fermentations and spoilage are designed to help understand how microbes occur in nature, how they get into foods, and how they bring about either desirable or undesirable changes. This information is used in control of fruit spoilage and in developing and controlling desired fermentation processes such as those involved in wine manufacture. For example, the role of specific microorganisms believed to cause softening of brined cherries is under continuing study. Comprehensive studies deal with the fermentative conversion of fruit juices to wine. These studies

range from fruit composition factors through study of yeast growth factors important in the fermentation to changes in wine during aging. The highly specialized study of the microbiology of olive fermentation continues. Other applied investigations are concerned with evaluation and enumeration of bacteria found in frozen fruit products.

Research directed to development of new or improved fruit products and processing technology continues to be a major part of the fruit utilization program. This work extends from study of the processing quality and suitability of selections and varieties to characterization of the chemical, physical and storage properties of a new fruit product. Basic studies deal with thermal processing requirements and include relationships to mechanism of heat transfer and thermal breakdown of various fruit constituents. Process design including methods, equipment, and plant layout receive study. Newer methods of freezing, dehydrofreezing, freeze-drying, irradiation and dehydration of fruits are under continuing investigation. Effects of chemicals, hydrocooling, refrigerated storage and controlled atmosphere storage and holding are evaluated in terms of the changes in product texture or structure, color and flavor. Product research is designed to provide basic information on product potential and functional properties. Development of processes or products to improve the utilization of fruits involves work on: dehydrated fruits; apple sauce; frozen fruit pies; apple-fruit juice blends; sherry wines; brined cherries; low sugar apple jelly; macadamia nuts; peach concentrates; and grape products. Research on fresh and roasted macadamia nuts has elucidated the quality characteristics of these products and defined optimum conditions for storage.

The total research effort on fruit utilization is approximately 59.1 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties.

1. Chemistry and cell structure of cherries for processing. Post-harvest bruising and aging of red tart cherries causes an increase in the firmness and drained weight of the canned fruit. An attempt was made to determine if there is an actual increase in cellulose content of the bruised and aged fruit. Tissues extracted with cupriethylenediamine (CED), a cellulose solvent, showed no increase in the amount of dissolved cellulose. Microscopic sections treated with CED showed no differences between soft and firm cherries.

2. Factors influencing apple texture. Further information on the chemical composition of apple cell wall constituents was obtained as a result of contract research (Maryland Agricultural Experiment Station). The amount and composition of the hemicellulose fraction was closely related to changes in texture of apples during storage. This fraction consists principally of D-galactose, D-glucose, L-arabinose, D-xylose, and D-galacturonic acid. Glucuronic acid was also present in variable amounts. During maturation and

storage, glucose decreased and glucuronic acid increased to an amount equal to galacturonic acid. Since glucuronic acid interferes with the measurement of galacturonic acid (from pectin hydrolysis) it throws considerable doubt on previous reports of the changes in pectin during storage.

B. New and Improved Food Products.

1. Instant applesauce to be market-tested. A market test is being conducted cooperatively with the Musselman Division of the Pet Milk Company on instant dehydrated applesauce. This product is made by coarsely crushing explosion-puffed dehydrated apple pieces. Approximately 3600 cans of the product, each containing enough material to yield 16 ounces of sauce on reconstitution, were prepared in the Engineering and Development Laboratory.
2. Washington state apples explosion-puffed. Fifty bushels each of Golden and Red Delicious apples grown in Washington state were supplied gratis by the Chelan County Industrial Development Council to determine their suitability for making into dehydrated products employing explosion puffing. Both varieties were shown to be suitable in making explosion-puffed pie slices, instant applesauce, and apple snacks. They were not as well suited, however, to the first two items mentioned as our Eastern grown York Imperials. Snacks made by explosion puffing for use with dry cereals evoked a great deal of interest on the part of potential processors in the Pacific Northwest.
3. New dried cranberry juice. A process developed several years ago in the Engineering and Development Laboratory for dehydrating fruit juices, while retaining their volatile aromas, has now been successfully applied to cranberry juice. The sweetened powder when mixed with water reconstitutes quickly to a sparkling full-flavor drink.
4. Improved apple cider. Diethylpyrocarbonate (DEPC) was effective in reducing the initial microbial count of fresh apple cider. As little as 50 ppm of DEPC destroyed 90 to 99% of the microorganisms in the fresh product. DEPC is more effective in clarified juice than in cloudy juice. Ultraviolet lamps were effective in partially sterilizing fresh cider. However, the color and turbidity of unclarified cider greatly reduced the effective depth of penetration.

C. New and Improved Processing Technology.

1. New puffing gun design. A gun for the explosion puffing of partially dehydrated fruits and vegetables has been designed. Construction drawings have been provided to industry and one company has already received several orders for commercial units. The new gun employs injected superheated steam in addition to external heat. This results in less heat damage to the product and much higher production rates.
2. Improved essence recovery equipment. A basic engineering study on the fractional distillation of complex mixtures of volatile fruit aromas has provided information for the design of commercial essence recovery equipment

capable of recovering essence components previously lost. This is particularly applicable to the aromas of Concord grape juice. Using the improved equipment design, methylanthranilate, an important aroma constituent, can now for the first time be recovered in good yield.

3. Evaluation of new equipment for cherry processing. Work on the quality of mechanically harvested cherries was continued, by cooperative field studies in Michigan. In connection with the mechanical harvesting of cherries, there are two related developments: mechanical destemmers and electronic sorters. Four types of commercial destemmers were evaluated in 1964. Each type of destemmer effectively removed the major portion of attached stems (87 to 98%) with only minor bruise damage. One available electronic sorting machine effectively eliminated the major defects (decay, limb rub, etc.) but was less efficient in picking out cherries with minor defects (scald, and light color). The capacity of this machine, under a wide range of operating conditions, varied from 742 to 2261 pounds of cherries per hour.

4. Processing characteristics of Eastern peaches. Over 100 new varieties of peaches were evaluated for processing characteristics as a result of contract research (New Jersey Agricultural Experiment Station). Several new varieties of freestones and clingstones were superior in flavor and color to the standard commercial varieties. Two new varieties were unusually high in vitamin A and one was also very high in citamin C.

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DECIDUOUS FRUIT AND TREE NUTS

Southern Utilization Research and Development Division, ARS

Problem. The peach industry in the Southeastern United States is dependent to a large extent on the fresh market. For example, in the South Atlantic States in 1962, 15,195,000 bushels of peaches were produced of which 12,237,000 bushels were sold on the fresh market; slightly less than 2,000,000 bushels were processed. A peach processing industry is needed in the Southeastern States to provide a profitable market for more of the edible peaches which do not meet fresh market standards and to rapidly convert a higher proportion of the overall crop to stable forms. Basic information, not now available, on the flavor components of peaches is needed to guide development of improved processed products from southern grown fruit.

Climatic conditions which favor rapid deterioration of fresh peaches both on and off the tree, erratic ripening periods and markets, and short lived peach orchards, are other factors contributing to the need for more extensively integrated fresh market-processing operations. There are technical problems preventing the more rapid development of the peach processing industry in the Southeastern States which must be overcome. Many of the peach varieties grown in the southeast require a modification of processing procedures to make satisfactory standard-type products. Still other varieties will not make standard-type products and new food forms must be found for them. Recent rapid advances in food science and processing technology make it possible through research to develop both new and improved peach products. These are needed to bolster the economics of the South's peach industry, as well as to provide the superior qualities, and greater convenience in food products, which the consumer now demands.

USDA AND COOPERATIVE PROGRAM

The Department has a program of basic and applied research on peaches being conducted under contract by the Georgia Agricultural Experiment Station, University of Georgia, Experiment, Georgia. Food chemists and food technologists conduct this research. Research to develop basic information on chemical composition and physical properties of peaches, particularly varieties grown in the Southeastern States, is in progress under one contract. Specifically, the objective of this research is to isolate, identify, and characterize the constituents of peach flavor and aroma, and acquire information needed to guide development of improved processed products from the fruit. Another contract, in the field of new and improved food products and processing technology, is concerned with research to develop optimum procedures for the production and preservation of puree and clear juice peach concentrates; to develop optimum procedures for the preparation and the handling under simulated commercial conditions of refrigerated fresh peach slices; to develop optimum procedures for canning Southeastern peaches; and to conduct experiments directed to the development of partially

dehydrated pasteurized peach products. Evaluation of different varieties of peaches, and of different processing variables are phases of the investigators. This research is carried out with the support of the Area Redevelopment Authority of the Department of Commerce.

The contract research involves a total level of effort of 2.0 professional man-years, 0.8 being on chemical composition and physical properties and 1.2 on new and improved food products and processing technology.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 236.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Basic Studies on Flavor and Odor Constituents of Peaches. A new project conducted under contract to the Georgia Agricultural Experiment Station is designed to develop basic information on flavor and odor constituents of peaches, lack of which had previously handicapped related research to impart optimum quality to new processed peach products. A large number of samples of Sullivan Elberta, Redglobe, Coronet, and Southland peaches have been frozen at various stages of maturity. Pits and peels have also been included. Samples of heated puree made from mixed varieties of peaches at soft ripe stage, samples of heated and unheated waste from the puree-finisher, and vapors trapped from the pulping machine and holding tank have also been collected. Other products prepared under the utilization contract (project SU-0-0-1(DC)) will be subjected to analyses of flavor and aroma.

In these four varieties of peaches, tannins (total tannin, leucoanthocyanin, and flavanols) appeared to decrease as the fruit matured through shipping ripe, firm ripe, and soft ripe stages. Within the same variety, the tannin content and the sensory evaluation of astringency were correlated, although this relationship was not demonstrable between varieties.

Peach volatiles have been shown to contain free fatty acids and carbonyl compounds. Removal of carbonyl compounds from peach flavor causes a marked change in the aroma, a result suggesting that these compounds affect flavor. When the volatile sulfur components of peaches were investigated, it was found that hydrogen sulfide was present in heated peaches; apparently the unheated peaches contained no volatile sulfur components. In a chromatographic analysis of the nonvolatile flavor components in soft ripe Sullivan Elberta peaches, the organic acids were shown to be mainly malic and citric acid, and the sugars mainly sucrose, fructose, and glucose. Thin-layer and gas-liquid chromatographic studies of peach samples before and after enzyme clarification indicate that pectin hydrolysis increases the recovery of volatile components. However, the possibility of an artifact has not yet been eliminated. Thin-layer chromatography has also been used to

demonstrate the presence of several free alcohols and aldehydes: ethanol, propanol, isoamyl alcohol, acetaldehyde, propionaldehyde, butyraldehyde, isovaleraldehyde, benzaldehyde. The findings reported will be checked through another season. (S3 2-44(C)).

B. New and Improved Food Products and Processing Technology

1. Development of New and Improved Processed Products from Southeastern Peaches. In other contract research, the Georgia Agricultural Experiment Station processed about 2000 bushels of peaches in its pilot plant during 1964 and is evaluating experimental packs of peach products. Clear peach juice concentrate. This product is already in commercial production, 4-1/2 million lbs. of B-grade peaches having been used to make 63° Brix for wine stock. It may also be useful in peach jelly, marmalade, waffle syrup, ice-cream, and fruit drinks. Puree-type peach concentrate. Puree was prepared from more than two dozen varieties, including peaches that ripened early, midseason, or late; that were clingstone, semi-cling, or freestone varieties; and that had poor, medium, or high flavor. Puree has been prepared from selected fruit for evaluation in ice-cream formulations. In addition, under supervision of GAES personnel, a commercial food processor reprocessed frozen puree to make a 2-fold puree-type peach drink, presently being test marketed by the Georgia Peach Commission. ERS and GAES are also conducting limited acceptance testing. To date, all evaluation is favorable. Chilled peach sections. In the 1964 season about 10,000 cases of jars of refrigerated fresh sliced peaches were prepared and successfully marketed. Firm ripe peaches with fully developed color made the best packs. The slices could be held in 30% syrup at 30° F. for more than two months, but preservatives did not increase the shelf-life. Two unsolved problems are the elimination of a "leafy" or benzaldehyde-type flavor and of the soft slick texture exhibited by some varieties. The commercial potential of the latter two products seems especially promising. Industry is exploring the feasibility of building a new plant or a plant addition to manufacture peach puree and refrigerated slices. Canned peaches. Peach halves were prepared from 17 varieties, with 4 sweeteners, and 8 cooking times. One variety each of early, mid, and late season fruit was processed in the shipping, firm-ripe, and soft-ripe stages. The packs are being allowed to equilibrate prior to evaluation. Drum-dried peach flakes. Preliminary tests have demonstrated that it is possible to make acceptable peach flakes from pulp-fortified peach puree. Additives such as sugar, starch, and a release agent improved the flakes, but the peach flavor is still weak. If such flakes can be produced economically, they may be useful in ice-cream, dry cereals, and similar products. Dehydrated peaches. Work on pasteurizing partially dehydrated peaches that had been blanched and vacuumized under 30% syrup containing half dextrose and half sucrose, with 0.1% ascorbic acid, was very encouraging. Twelve varieties and 71 lots were prepared for evaluation. Irradiated peaches. Irradiation pasteurization of peaches with 50,000 to 200,000 rad destroyed the chlorophyll and intensified the yellow and red color in the skin; greatly reduced peach flavor and aroma; and apparently intensified sourness, bitterness, and tartness. It did extend the shelf life of the fresh peaches from 4 to 10 days. (SU-0-0-1(DC)).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None

DECIDUOUS FRUIT AND TREE NUTS

Western Utilization Research and Development Division, ARS

Problem. Fruits and nuts are valued for their unique flavor, color, and natural vitamin content. In the period of abundance at harvest time, markets are glutted and growers often do not get an adequate return. Crops are perishable, and processing to preserve their unique qualities is difficult. No processed fruit retains completely the fresh values, although many highly acceptable products exist and about half of the fruits and nuts marketed in the United States are processed. Processing makes these commodities available to consumers the year around, and has opened new markets for producers. The proportion of processed commodities is steadily increasing but is dependent upon a continuing flow of new knowledge. Processing to preserve color, flavor, and texture presents many problems generally, and each new product requires the application of much scientific and technological skill.

The freezing process for preserving certain fruits keeps the products excellent at near fresh fruit condition. In spite of the gains in quality realized in freezing, many unsolved problems remain. The enzymatic browning of frozen peaches and the sloppy texture of frozen strawberries on thawing are two good examples.

Frozen fruits require expensive low-temperature storage and transportation facilities. The expense is greatly reduced by removing a portion of the water from the products. Orange and other fruit juice concentrates are well established in U.S. markets, and dehydrofrozen apple slices (rapid drying to 50% bulk weight and then freezing) are just becoming well established. Many other fruits and fruit juices should be amenable to concentration. Products of this type, however, are not so well adapted for export as those which do not require refrigeration.

The maximum weight reduction can be achieved through dehydration. The drying of fruit juices has been successfully accomplished by the vacuum puff drying and foam-mat drying processes. The latter is under intensive study, because it can be carried out at atmospheric pressure and consequently offers economy in processing. This process must be worked out in detail for many, as yet untried, fruit purees and juices and on pilot-plant scale for those products that show promise. Flavor recovery and the incorporation of recovered flavor in solid carriers for addition to the dried products require technological and basic chemical study. Essence recovery techniques developed for fruit juice concentrates are not completely satisfactory for this purpose.

Dried and canned fruits are now widely used in the U.S. and abroad. The popularity of dried fruits overseas and in this country would grow if stable,

higher moisture dried fruits were available and if lower levels of sulfur dioxide could be used without loss of quality.

Container costs for canned fruits limit the shipment of these products overseas. A solution of the container problem may be found in the use of lightweight fiber, foil, or plastic containers and aseptic filling procedures.

Fruit growers need new varieties of tree fruits and berries suited to processing and resistant to diseases endemic to each region of production. Utilization research is required in cooperation with farm research to assure growers of a market for fruit in the processing industry.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a broad program of basic and applied research on deciduous fruits and tree nuts is conducted at the Division headquarters at Albany, California; in field stations at Pasadena, California and Puyallup, Washington; by contracts in Davis and Los Angeles, California, Fort Collins, Colorado, and Geneva, New York; by grant at Cambridge, Massachusetts; and by grant funds under P.L. 480 in Israel and India. Fundamental research is conducted on fruit constituents that are involved in the flavor, color, and texture of fruit products, and includes development of laboratory tools to isolate and characterize individual components, investigation of such components as they occur naturally and as they are altered by operations involved in preservation, and the relationships between the components and the product values being preserved. Applied research is conducted to develop new and improved processes and products that will increase utilization of fruits and tree nuts, including the development of high-quality concentrated and dehydrated products and more stable shelled tree nuts and the selection of improved processing varieties. Pioneering research on plant enzymes is also conducted.

The Federal program of research in this area totals 41.3 professional man-years, including two scientists whose salaries are provided by two cooperators (Dried Fruit Research Advisory Committee, whose membership represents the California Raisin Advisory Board, the Dried Fig Advisory Board, the California Prune Advisory Board, and the Dried Fruit Association of California; and the Walnut Control Board - one each), under Memoranda of Understanding; six grants and contracts providing research at a rate of approximately 4.7 professional man-years per year. Of this number, 25.8 are assigned to investigations on chemical composition and physical properties; and 15.5 on new and improved food products and processing technology. In addition, the Division sponsors basic research on fruit by means of three P.L. 480 grants.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 236.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Fruit Pigments. Red, purple, and blue fruit colors come from phenolic compounds known as anthocyanins. Fruits lose color when anthocyanins change to colorless leucoanthocyanin compounds. From model systems of synthesized flavylium salts and phloroglucinol, resorcinol, and catechin we postulated that the reaction is a condensation of the pigment with other natural phenols. Further studies with natural catechin strengthened the hypothesis. Theoretically ascorbic acid and simple sugars, such as fructose, could destroy color by similar reaction. Studies at the University of Delhi in India, supported by Public Law 480 funds, have shown that anthocyanidins react with ketones and lose color in fruit products. Leucoanthocyanidins were isolated for study from pears, prunes, quince, peaches, cherries, and persimmons in this work.

Contract research at UCLA established that the principal polyphenolic pro-anthocyanidin of avocado is a condensation product of two phenolic compounds. The proanthocyanin isolated from avocado is a new type of natural flavonoid compound. Its structure led them to expect that red anthocyanin pigments would develop under acid conditions and this was demonstrated.

Phenolic components of apple juice are involved in a protein complex that eventually settles out of clarified juice. Chemical examination of washed sediment revealed a phenolic component. Although it contained little nitrogen, acid hydrolysis split off a number of amino acids indicating protein was involved. Catechins and leucoanthocyanidins were observed in the original clarified apple juice but could not be detected after sedimentation. These observations were obtained in contract research at Colorado State University.

The degradation of carotenoid pigments (yellow, orange, and red) was studied in acetone or methanol solutions with hydrochloric acid. Carotenoids vary widely in reactivity with acid. Reaction products of the degradation were identified. Color loss of both anthocyanin and carotenoid pigments in fruit products has generally been considered to be oxidative, although acids have been implicated in carotene transformations. Other mechanisms for anthocyanin loss were suggested by other investigators in this field but with no clear-cut understanding of the type of chemical reactive groups involved and no knowledge of the nature of the products of the reaction. Information gained from in-house, contract, and grant research is contributing a deep chemical understanding of condensations involving anthocyanins and other natural compounds. This new knowledge should ultimately lead to practical controls for the color of processed fruit products.

2. Enzymic Browning of Fruit. In the enzymic browning of fruit, phenolic constituents are converted to colored compounds. Adding a methyl group to such compounds by the enzyme methyltransferase system blocks enzymic browning reactions. Basic investigations are in progress on the methyltransferase enzymes and on the phenolic substrates of the browning reaction. Molecular

conformations of quinic acid, four structural isomers of chlorogenic acid, three of isochlorogenic acid, and five of dehydroquinic acid were determined by nuclear magnetic resonance spectroscopy and optical rotatory dispersion studies. Catechol-0-methyltransferase from plant sources was fractionated and purified so that its specific enzymic action could be more narrowly characterized. Differences in the specific activity of plant 0-methyltransferase from animal 0-methyltransferase were determined. Differences in the molecular positioning of methyl in phenols by the enzymes serve a useful function in organic synthesis of methoxy phenolic compounds and may ultimately make possible better control of fruit browning.

These basic findings were immediately applied to preservation of peeled apples for bakery use. Dipping peeled apples in an acid solution alters the surface pH and allows native methyltransferase enzymes to inhibit browning so that the product may be held under refrigeration for several weeks without browning. An earlier commercial process prevented browning by treatment with sulfur dioxide in the dipping solution. By use of the pH adjustment related to methyltransferase activity, it is possible to materially reduce the sulfur dioxide concentration so that flavor and texture of the treated apples were substantially improved.

Studies on enzymic browning of fruits are also conducted at the Hebrew University in Jerusalem, Israel under P.L. 480 grant funds. In these studies the enzymes that change colorless phenolic compounds to reddish brown pigments are being isolated from various fruits. These enzymes, phenolases, are contained in the chloroplasts and mitochondrial structures of plant cells and are released as the fruit ripens. Their release accounts for the increasing tendency of fruit to brown as it ripens. Phenolases were isolated from apples, peaches, and for comparison from lettuce seeds, sugar beet leaves, and potato tubers and characterized with regard to their browning activity with various phenolic substrates and the dependence of their activity on pH. Improved procedures were developed to remove the enzymes from particles in the plant cell to which they are tightly bound. Three different enzyme fractions were extracted from chloroplasts of apple. Chemical inhibitors of phenolase were found and are being used to obtain more detailed knowledge of the mechanism of inhibition. These investigations were extended to nine different varieties of apples and four of peaches. The enzyme systems differed in different varieties of apples, but were the same in all varieties of peaches.

3. Chemical Origin of Plant Structural Tissue. Investigations have been made on the cell wall and other structural tissues of plants; how they form and degrade during growth and ripening of fruits. Myoinositol is an active depot of carbohydrate material. Because it changes to pectin, hemicelluloses, and cellulose, it must be important in the development of texture in ripening fruit. In-house research on myoinositol was concluded while basic investigations in this field are continuing by grant research. A grant was made to the Cell Biology Laboratory, Harvard University to obtain information on the formation and physical structure of fruit tissue cell walls. They are working on the internal morphology of microtubules of plant cells. Electron

microscopy provided evidence supporting the contention that these minute structures are tubular and are composed of 13 subunits linked in a circular arrangement to form a central bore or channel. Protoplasmic streaming in cells is also under observation. This streaming appears to result from a contractile system that does not involve the microtubules. The liquid phase of the main streaming channel is connected to the surrounding environment by a complicated interlinking of tributaries with only the slime layer as an external barrier. Investigations of the streaming phenomena will be concluded because they did not reveal a connection with the microtubules.

A P.L. 480 research grant has been made to the National Taiwan University, Taipeh, Taiwan, China for basic investigations on the formation of hemi-celluloses and nitrogenous compounds associated with cell walls and of intermediates and enzyme systems involved in hemicellulose synthesis.

4. Fruit Flavor Components. Fractions of the volatiles from apple essence were separated with a packed column and a non-destructive detector. The fractions were evaluated for aroma and their structure investigated. Characteristic apple aroma seems to come from only a few individual compounds whose structure and sensory characteristics are being established. Relative odor intensities of apple essence fractions were determined by a combination of gas liquid chromatography separations and test panel threshold measurements. Panelists sniffed each fraction as it was separated by liquid-gas chromatography. The fraction with the most intense odor (i.e., the one detectable at the most dilute concentration), was the fraction present in least amount. Two samples of Delicious apples, one each of Jonathan and McIntosh apples, and a mixture of juice, including those four samples plus juice from Rome Beauty and Northern Spy, were compared by this separation and evaluation technique. For all five of the samples tested, the judges picked the same small chromatographic fraction as being the best apple aroma. Chromatographic estimate of concentration of the intense fraction was determined for apple essence stored under different temperatures. The results indicate the possibility of using the concentration of this fraction as a basis for establishing processing control limits for desirable aroma in apple products and illustrates the possibility of making objective instrumental measurements that have sensory meaning.

5. Pioneering Research. A Pioneering Research Laboratory conducts basic research within the Western Utilization Research and Development Division to discover, identify, and characterize the enzyme substrate systems responsible for formation and disappearance of plant constituents and structures.

Ethylene Metabolism in Plants. When ethylene is absorbed from a low concentration in air by harvested green, but mature, fruits, many ripen faster than normal. Although ethylene has been used commercially for many years to ripen fruit, its mechanism is unknown and is being investigated. With the avocado as an experimental subject, the complicated ethylene chemistry was studied. Carbon and hydrogen from ethylene enter into different series of chemical reactions in the fruit. About one-eighth of the total hydrogen was incorporated in the methyl group of toluene, but only a minute amount of the

carbon ended in toluene. A smaller amount of the ethylene was found in another hydrocarbon, benzene. The proportion of original ethylene, carbon, and hydrogen found in toluene and benzene suggests that these two end compounds may be products of separate reaction chains and not successive steps in a single chain of reactions.

Biochemical Synthesis of Structural Material. Enzymic synthesis of structural plant tissues, especially the wall substance of plant cells, is being investigated. The properties of such tissues mainly determine such textural characteristics as crispness, turgidity, and ability to maintain structural integrity through boiling, freezing, or drying. These enzyme systems can only be investigated in growing tissue, but growing tissue always has accidental variations. Two laboratory techniques are used to get more uniform working materials. One technique involves growing plant tissue cells in a complete synthetic nutrient solution. Another method is to use newly-formed plant tissues in oat seedlings that have been germinated and grown under very uniform conditions. When the amino acid proline was added to the solutions of plant tissue cultures, it was quickly incorporated into peptides and proteins that form a part of new cell walls. At the same time hydroxyproline, which forms by enzymic oxidation of proline in air, appeared substantially in the cell wall proteins but very little in the protoplasmic protein within the cell. Protoplasmic protein incorporated proline very rapidly, however. In the cell wall the two amino acids are apparently firmly associated with carbohydrate materials such as pectin, hemicellulose, and cellulose, which are mainly responsible for the mechanical properties such as stiffness and elasticity. Application of a potent growth promoter, indolacetic acid, to the live oat seedlings weakened their wall structure. Enzymic removal of pectins or various proteins from the seedling walls did not further weaken them, indicating that the strength is mainly provided by hemicellulose and cellulose material.

Enzymic Mechanism for Replication of DNA. Special enzymes in growing plant tissue are involved in reproducing the genetic pattern in new cells of growing plants. Desoxyribonucleic acid (DNA) duplicates itself under proper conditions. Research is conducted to discover how this replication of DNA is modified if DNA is complexed with histones, a class of proteins rich in either arginine or lysine which readily associate with DNA molecules. In a cell-free test tube system, replication of DNA molecules proceeds if a DNA-histone complex is used instead of DNA. However, the synthesis proceeds slower. In such experiments the DNA-histone complex can be either a natural product, such as one that has been separated from pea embryos, or it can be synthesized from certain purified proteins and DNA. In either case the DNA will be replicated. When a lysine-rich histone was used, only a little new DNA forms, but if an arginine-rich histone was used, somewhat more DNA appeared. Many plant physiologists wonder how tissues of a plant can arise from a single cell but manage to differentiate from one another and produce entirely different tissue structures at different locations and at successive stages of the life cycle. A current hypothesis identifies the mechanism that accomplishes this differentiation with the histones that complex with DNA. The DNA replication system and the enzymes that monitor it are being explored.

Plant Protein Synthesizing Enzymes. The process of protein synthesis in a plant consists of the orderly assembly of all the amino acids required to form the protein and their attachment, one after another or in groups, to build up structures whose pattern is specified by ribonucleic acid (RNA) molecules in the plant cells. Synthesis is accomplished through reactions whose first step involves activation of an amino acid molecule by a specific enzyme and a nucleotide triphosphate to furnish necessary energy. A polymerizing enzyme then attaches the activated amino acid to the emerging protein structure. The reaction in which the activated amino acid-phosphate-enzyme complex is associated with a molecule of RNA is under investigation. A strong solution of purine disrupts the helical secondary configuration of RNA that is believed to be associated with the specificity of this molecule for association with a particular amino acid. We don't know whether the destruction of this helical arrangement interferes with the ability of RNA to associate with an amino acid. Research to date demonstrated that the reaction that activates an amino acid is not affected by the presence of purine. The effect of purine on the attachment of amino acid to a protein chain will now be studied.

Biochemistry of Plant Steroids. Steroids sometimes control enzymes. Steroids and related compounds are being investigated in cooperation with the Division of Biology at the California Institute of Technology. The major steps in biosynthesis of certain steroids from acetate to diosgenin were identified by administration of radioactive tagged precursors to growing plants or plant tissue homogenates and isolating radioactive products by thin-layer chromatography. A number of chemical compounds known to accelerate or retard particular enzyme reactions were studied to determine the nature of their action on the plant production of growth stimulator. A tagged steroid precursor both with and without added retardants was added to the fungus *Fusarium*. Radioactive gibberellin, an active growth promoter, was isolated from retardant-free cultures but was not found in cultures containing the retardants.

Chemical Alteration of Enzymes. Chemical modification of pure crystalline enzymes in order to locate active regions in protein molecules and to determine relationship of molecular structure to enzymic activity is being investigated by a collaborator with the Pioneering Research Laboratory whose research is supported in part by a grant from the National Institutes of Health. This investigation uses isolated proteins which combine with enzymes to inhibit enzymic action. A protein was isolated from the potato and determined to be a very potent inhibitor of the protein-splitting enzyme, chymotrypsin. The inhibitor, the enzyme, and the complex of the inhibitor and enzyme have all been crystallized. The complex is inactive either as an enzyme or an inhibitor, but it was possible to disrupt the complex and resolve it into active enzyme and active inhibitor. The complex contained four molecules of the enzyme per molecule of inhibitor. This is the first known instance of a combination of a proteinaceous inhibitor with a protein-splitting enzyme in any ratio but 1:1. Such knowledge should be helpful in determining the active center of the enzyme. The purified chymotrypsin inhibitor is used in eye surgery. Chymotrypsin has been effective in the treatment of cataract, but a safe way of stopping the protein-splitting action when desired was needed. The new inhibitor makes this possible and

is not toxic in the quantities required for eye surgery. The effect of changing the structure of chymotrypsin by chemical reaction was also studied. Others have shown that trypsin, another protein-splitting enzyme, loses its ability to complex with proteinaceous inhibitors after acetylation but acetylated chymotrypsin was inhibited by the potato juice inhibitor just as plain chymotrypsin. This result is another clue to the active center of this enzyme.

B. New and Improved Food Products and Processing Technology

1. Dried Fruit Products. Research on new and improved dried fruit products continues, supported in part by the Dried Fruit Industry Research Advisory Committee which provides the salary of one of the scientists assigned to this work. A dried fruit product suitable for inclusion with dry breakfast cereals was prepared from prunes, dried figs, or dried apricots. Dried fruits were ground to a paste, dried on a double drum dryer to a desired moisture content, ground into a powder, and pressed into suitable size disks for inclusion in breakfast cereals. Adjustment of drying conditions and tabletting pressure, produces disks dry enough that they do not lose moisture to the cereal and crisp enough to keep an attractive texture for a suitable period after being immersed in milk with the cereal. Samples of this product were supplied to cereal manufacturers for evaluation.

A modification of drum drying has produced a good apple sauce flake, both sweetened or natural, smooth or chunky. Air is drawn over the drying film on the revolving drum surface and then a chilled air blast hits the film just before it is scraped from the drums. The method is now in use by a processor in Washington State and his product is being used by cake mix manufacturers. The product has also been adapted for the Apollo space feeding program.

Heat treatments to prevent setting of raisin paste were simplified by heating whole raisins in either hot air or steam prior to grinding, and packaging the ground raisins while still hot. The treated raisin paste remained soft and pliable during prolonged storage and is, therefore, useful in bakery formulations.

2. Fruit Dehydration. Microwave heat treatment for cut fruits accelerated subsequent dehydration. The heat inactivation of enzymes made possible a reduction in sulfite addition to such fruits. Microwave heating was also used to sterilize flexible packages of fruits that were packed in the moisture range between 35% and 85%. Further advances were made in osmotic drying of apple chips. Thin apple slices, dipped in salt-citric acid solution, were mixed with sugar and held for several hours or more. Moisture passed from the fruit to the sugar turning it into syrup, which was drained. The product was then dried for two to three hours in a vacuum oven with a high temperature source (212° F.). The apple chips so produced were light in color although no sulfur dioxide had been used, and had a good apple flavor. The texture was crisp because of the rapid vacuum drying to a moisture content of about 1%. Although this product is stable against non-enzymatic browning, its resistance to oxidative deterioration presents a problem for future research. Syrup formed from the sugar and fruit moisture in this osmotic

drying process can be used for flavor concentrate and sweetener in the manufacture of experimental ice cream, or in an integrated apple processing plant it could be used for canning syrup and for canned apple sauce.

Microwave energy has also been used to puff partly dried apple sauce to insure rapid final drying and ready rehydration. In this method, apple slices are degassed in vacuum and the vacuum is broken with a mixture of CO₂ and SO₂ gases. The slices are dried to 20% moisture in warm air and treated with microwave to remove 1 to 2% moisture, thereby puffing the product which is then air dried to its final moisture content.

A gelled apple sauce product was developed so it can be used on a warm plate without losing its form, used for molded salads, etc. The product is formulated with low methoxyl pectin and calcium salt to harden the gel. Commercial market tests are currently under way.

3. Texture of Processed Fruit. No large-scale softening of 1964 brined cherries was reported on the West Coast, perhaps partly because of the results of cooperative studies conducted with Oregon and Washington State Agricultural Experiment Stations over a several-year period. Increasing numbers of brined cherry processors used the puncture meter as a quality control instrument as developed by the Western Utilization Research and Development Division to indicate possible softening early when the deterioration could be arrested by drawing off the brine, heating it, and then adding it back to the cherries. High calcium brines have also been used as insurance against texture deterioration.

Studies were conducted on the reuse of old brines. Cherries processed in brines reused several times were firm and had acceptable texture. Anthocyanin build-up in the brine could discolor brined cherries in storage if all the natural pigment was not bleached out prior to dyeing the cherries. Heavy metal ions such as copper, iron, and manganese in amounts over 5 p.p.m. contribute to the formation of undesirable color. Reuse of calcium bisulfite brines for more than one season reduces costs of cherry brining not only in purchase of supplies but also in the more serious problem of disposal of waste brines.

4. Grape Juice and Grape Products. Research on viniforous grapes has been extended to studies of wine technology with a small in-house research effort supplemented by informal cooperation with commercial wine makers and by contract research. Wine grapes invaded by the mold Botrytis cinerea in the vineyard or inoculated by mold spores sprayed on harvested grapes in a controlled environment yield wines generally considered greatly superior to those from uninfected fruit of the same variety. The better Sauternes from France, Tokayi Essencz, Passito de Caluso, and Edelfaule Auslese are such wines. Investigations have been centered on the novel approach of fermenting grape must (crushed grapes and juice prepared as a first step in wine making) or juice with Botrytis rather than allowing it to grow on the whole fruit. For a successful controlled fermentation of this type, competing molds and micro-organisms must be controlled to allow the Botrytis organism to predominate. Heat sterilization or pasteurization harms flavor and color so non-thermic microbial control is used. Diethylpyrocarbonate, sulfur dioxide, and benzoate of soda are three sterilants that have been used experimentally.

Beneficial effects have been obtained by submerged culture of Botrytis cinerea and by addition of Botrytis cinerea mycelium extracts to the must or the grape juice. Pectin-splitting enzymes from the mold make the wine easier to filter. Most important, Botrytis fermentation improved the flavor substantially and wines made from Thompson seedless juice (characterized as rather flavorless) show considerable similarity to French Sauternes. Moderate scale wine improvement experiments were conducted cooperatively in two commercial wineries. However, for the first year's experimentation bonification of wine varietal grape rather than Thompson seedless grapes were used. Larger-scale experiments and experiments with Thompson seedless grapes are anticipated during the next year.

Osmotic concentration of grape juice and wine was accomplished without application of heat by drawing water from wine into a concentrated salt solution through a dialysis membrane. Preliminary studies with various dialysis membranes indicate the possibility of removing alcohol from wine without using heat but improved membranes are probably necessary. The product would be a low-alcohol or nonalcoholic beverage with wine flavor.

Effects of diethylpyrocarbonate as a prefermentation sterilant for alcoholic fermentation, in addition to its use in studies of the Botrytis cinerea treatment, are under continuing investigation. The use of this apparently harmless compound which hydrolyzes rather rapidly into ethanol and carbon dioxide could obviate or reduce the use of sulfite in white wine production and minimize the sulfhydryl type odors and residues of sulfur dioxide in such wines.

Contract research was initiated at the University of California at Davis on new or improved methods for separation of juice from grape pulp, skin, and seeds (must). Flash steam heating of red grapes to improve color extraction from skin was studied from the standpoint of its effects on aroma. Gas liquid chromatography showed that certain esters (isoamyl acetate and ethyl caproate) develop to higher levels in heat-treated juice. Recovery of fermentable sugar from grape pomace was also investigated under this contract. Countercurrent washing of pomace appeared to provide a satisfactory recovery of sugar.

Contract research was initiated at the New York Agricultural Experiment Station in Geneva on the chemistry of undesirable precipitates that form during the production of wine in order to develop improved processes and fining material to remove haze and precipitates from wines.

5. Processing Quality of Varieties of Northwest Fruit and Berries. Fruit and berry selections are evaluated in cooperative research with the Washington State Agricultural Experiment Station. Six varieties and 21 hybrid selections of strawberries were evaluated. The hybrids represent the best of 10,000 seedlings which first produced fruit in 1960 and, although none were found to possess processing and cultural characteristics that justified introduction as new varieties, several are promising from some standpoint and are

being kept by the geneticists at the Experiment Station for breeding stock. Earlier evaluations on a new hybrid for preserves played a part in its release in Oregon as the Banks strawberry variety. In cooperative work with Washington, Oregon, and California Agricultural Experiment Stations frozen strawberries were compared for processing quality. Processing evaluation of 18 hybrid selections of raspberries indicated one hybrid is outstanding. It will now be propagated for introduction as a variety in the State of Washington. These resistant hybrids should fill an existing need where present susceptible varieties are declining.

Preliminary evaluation of processing quality of pears was undertaken to determine whether or not faults had been introduced into new strains being developed for simplifying mechanical harvest. For example, introduction of dwarfing root stocks, plant hormone sprays for shortening pear tree internodes, and gibberellin sprays for setting pear fruits after severe frosts during bloom. First-year evaluation indicated hard end disorder and offset stems occurred frequently. Gibberellin sprays caused misshapen fruit and abnormal cores. Observations must be continued during several growing seasons to be significant.

6. Improved Fruit Juices and Fruit Juice Processes. An improved apple juicing system, in which a conventional rack and cloth press was replaced by a sanitary basket centrifuge and a stainless steel continuous vertical screw press, was developed and used in test runs at commercial apple processing plants in northern California and Washington. In most cases the yields of juice and percentage of solids in the juice are both significantly better than those from a rack and cloth press. Gross juice yields range from 160 to 190 gallons per ton of fruit, depending upon maturity and variety. Addition of a press aid before centrifuging was essential. The system lends itself to full automation and is best suited to large-scale commercial operations because of sizable capital investment involved. Following publication of results an apple processor in British Columbia installed the system.

Engineering studies to improve methods of transferring heat to fruit juices and purees during processing have centered on factors affecting the fouling of heat transfer surfaces. Because rotating steam coil heat exchangers have become widely used in open pan evaporation, particularly for tomato juice, equipment was fabricated to initiate studies on fouling of such heat transfer systems. In preliminary tests, steam condensate in the coil resulted in an uneven temperature gradient which affected the experimental values, and a modified rotating steam coil is being designed for further work. Control of heat input for evaporating food materials is hard because juices or purees entering the system are not uniform. To compensate for variable total solids entering an evaporator, an automated feed forward system is being developed. In continuous operation the total solids of juice entering the evaporating system would be sensed and used to activate the heat input as the juice entered the evaporator. A mathematical model using a realistic variety of operating parameters was developed simulating a feed forward system on an

analog computer. The feasibility of the system was proven and the next step will be to prove out the control under operating conditions. Two in-line optical refractometers to determine total solids of input juice and outflow concentrate and an analog computer will be installed in a long tube evaporator and experiments conducted to confirm the mathematical simulation.

7. Stabilizing Shelled Nuts. Deterioration of shelled nuts is presumably due to the oxidative changes in unstable lipids. Research was initiated on the analysis of walnut oil, and a modification of laboratory procedures to facilitate this analysis was successful. It involved a direct, rapid, convenient, and quantitative transesterification of walnut oil glycerides using a boron trifluoride catalyst. The method should be applicable to similar studies with other fats and oils.

Contract research on the stability of fresh and roasted Macadamia nuts at the University of Hawaii was terminated. The final report revealed that only minor differences were observed in quality and chemical characteristics of three varieties used. Roasted kernels maintained their quality better than raw kernels. Flavor deterioration closely paralleled darkening of kernels. Kernel stability increased with decreasing moisture content down to about 1% moisture. Kernel stability decreased with increasing storage temperature. Quality changes were essentially identical for kernels stored in light or darkness. Satisfactory conditions were found for processing and packaging shelled Macadamia nuts that are stable.

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VEGETABLES

Eastern Utilization Research and Development Division, ARS

Problem. Vegetable growing occupies over 3 million acres, with a yearly farm value of a billion dollars. Utilization as processed rather than fresh vegetables provides a constant source of supply with less price fluctuation. Basic compositional research is needed to provide knowledge to constituents responsible for color, flavor and texture of vegetables and the changes these constituents undergo during processing, storage, and distribution. There is also need for application of these results to developmental research on new products and new and improved processing technology. Consumer preference is shifting to "convenience" foods. An even greater emphasis on quickly prepared foods is evident in modern military feeding where high bulk density, nonrefrigerated, and rapidly rehydrating products are of primary importance.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program employing chemists and chemical engineers in basic and applied research on vegetable processing and products. The Federal work is conducted at Wyndmoor, Pennsylvania. The scientific effort assigned to this area totals 5.9 professional man-years and is currently engaged in research on new and improved products and processing technology.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations conduct a broad program of basic and applied research on vegetable processing and products in order to maintain the place of vegetables in the diet and to overcome problems associated with the perishability and seasonality of vegetable crops. Research on the adaptability and evaluation of vegetable varieties for processing is a continuing service to vegetable breeding programs. Each promising introduction or variety is evaluated with respect to processing yield and characteristics.

Increased public concern with protection of the food supply from pesticide residues has resulted in initiation of three regional projects to study reduction or removal of residues from food products. Since commercial food processing and preparation procedures vary, the effect of these processes on residue removal is being evaluated. There is also an urgent need to develop rapid, sensitive methods for routine determination of pesticide residues on foods undergoing commercial processing. Data relative to chemical form, distribution and persistence is being amassed. Vegetables are included in the crops being studied. One objective of regional project NEM-30 involves study of the basic physiology and chemistry of changes taking place in post-harvest handling and processing.

Characterization of raw materials extends to consideration of the effects of various production variables upon processed product quality. Mechanical harvesting and the associated effects upon ultimate processed product quality are receiving increased study. The degree of correlation or association

between color, flavor and texture in fresh and in processed items continues to be a major concern.

Basic chemical and physical properties of vegetables are related to product acceptance and quality. Research on vegetables in this area ranges from standard composition studies to highly specialized analysis for mineral components. Research aimed at describing the biological changes that occur in vegetables at different stages of maturity continues. The role of enzymes and pigments in vegetables also receives continuing study.

Basic microbiological research centers around the high resistance of bacterial spores to heat and the adverse effects extreme thermal process requirements have on canned vegetables. Microbiological studies extend from determination of thermal process requirements to study of the natural flora of fresh vegetables. The radioresistance of bacterial spores and use of combined antibiotics and heat are carefully researched.

Processing technology research is directed to studies of freeze-drying, brining, canning, fermentation, hydro-cooling and controlled atmosphere methods. The comprehensive study of the effects of controlled or modified atmosphere on the biochemical, physical and quality characteristics of various vegetables continues.

New or improved product development research seeks to improve or perfect such items as "quick cooking" peas and beans, beet chips, various snack items, soups; and new sauerkraut products. Basic information relative to composition, nutritive value and functional properties is emphasized.

The total station research effort devoted to vegetable processing and products is 64.1 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. New and improved products.

1. Quick-cooking dehydrated vegetable pieces of high density. Because of their expanded, porous, structure, explosion puffed dehydrated vegetables tend to be more bulky than their conventionally dried counterparts. It has recently been found that this bulkiness can be eliminated by compressing the pieces between rolls immediately after puffing while they are still moist. On final drying the compressed pieces have a bulk density no greater than conventionally hot air dried pieces of the same original size and they rehydrated just as quickly and regain their shape as though they had not been compressed. This finding will significantly reduce the cost of the finished packaged product.

B. New and improved processing technology

1. New puffing gun design. A gun for the explosion puffing of partially

dehydrated fruits and vegetables has been designed. Construction drawings have been provided to industry and one company has already received several orders for commercial units. The new gun employs superheated steam in addition to external heat. This results in less heat damage to the product and much higher production rates.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

New and Improved Products

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New and Improved Processing Technology

Heiland, Wolfgang K., and Eskew, Roderick K. 1965. A new gun for explosive puffing of fruits and vegetables. U. S. Agricultural Research Service, ARS 73-47, 7 pp.

VEGETABLES

Southern Utilization Research and Development Division, ARS

Problem. Although extensive progress has been made in recent years in developing stable, attractive, and convenient to use vegetable products, new and improved processed products must be developed and means of stabilizing perishable vegetables provided to minimize the adverse effects of seasonable surpluses and unfavorable markets, and to provide an adequate supply of good food for a growing population. Product quality needs to be improved and processing cost reduced through the adaptation and application of the latest technological developments and nutritional findings. For example, a major problem of the cucumber industry, since most of the crop is brine-cured, is to improve the curing process so that no loss occurs in the value of the cucumber during the brine-curing and storage process and the cost of processing is reduced. New pure culture fermented products are needed to more fully utilize cucumbers and many other vegetables in attractive consumer items. As another example, a precooked, dehydrated, sweetpotato product has been developed which usually has good shelf life when sealed under an inert gas. It reconstitutes to a product having the characteristics of freshly cooked and pureed sweetpotatoes. Applied research on a pilot-plant scale is needed to obtain additional engineering and processing data applicable to commercial production of flakes from sweetpotatoes of different variety and environmental history. Basic research is needed to further improve quality and storageability of the product, and to provide the scientific basis for the development of a process for making excellent flakes from uncured, freshly dug sweetpotatoes. There is a continuing need in the use of vegetables for processing to investigate the characteristics of the raw material as these characteristics are affected by climate, soil, cultural practices, breeding and the like. Celery, already an important flavoring ingredient, could become much more important if the factors and constituents responsible for the intensity, variableness, and stability of its flavor could be controlled in processing, and processed products of improved flavor and convenience could be developed. Many vegetables grown in the Southern Region differ in their chemical and physical characteristics from the same crops grown in the more temperate regions. Tomatoes are a good example in that they are frequently poorer in color, flavor and texture. Several vegetable crops, including sweetpotatoes, hot peppers, okra, and Southern peas, are grown almost exclusively in the Southern Region. More utilization research is needed to complement the Federal and State production research programs and to provide cooperation in the form of composition and processing studies. This kind of cooperation is needed to prevent the release of breeding selections which are entirely unsuited for processing.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving biochemists, organic chemists, microbiologists, food technologists, and chemical engineers

engaged in both basic and applied utilization research studies on vegetables of the Southern Region to develop new or extended uses for these commodities.

Research to develop basic information on chemical composition and physical properties of vegetables, their products and byproducts, is conducted as a basis for efficient research in developing new and improved food products and processing technology. Investigations of the flavor and aroma components in natural and pure culture fermented cucumber pickle products are carried out at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina, to provide the basis for producing pickle products of greater consumer acceptability. The North Carolina and Michigan Agricultural Experiment Stations, and the Pickle Packers International, Inc., cooperate in this research. Other research at Raleigh, conducted at and in cooperation with the North Carolina Agricultural Experiment Station, is concerned with basic investigations of the chemistry and biochemistry of the carotenoid pigments in vegetables in relation to variety, maturity, and environmental factors, to facilitate the development of improved and more attractive processed products. Additional research on chemical composition and physical properties is being carried out under a grant at the Research Triangle Institute, Durham, North Carolina, on elucidation of the molecular structure and chemical characteristics of the pectinase inhibitor in sericea forage and other plant sources which has proven effective in preventing softening of cucumbers in brine curing.

In the field of new and improved food products by processing of vegetables, both basic and applied research are being carried out at New Orleans, Louisiana, to improve the stability of the flavor of precooked, dehydrated sweetpotato flakes packaged in air, and to improve the processability of uncured sweetpotatoes and their flake characteristics. These are two major problems still facing the new sweetpotato flake industry. Current research approaches involve evaluation of antioxidants and other additives for flavor stabilization, and investigation of commercial amylolytic enzymes in accelerating the curing of sweetpotatoes. Basic studies of the properties of native amylolytic enzymes of the sweetpotato are included. Close cooperation is maintained with the Louisiana Agricultural Experiment Station, and industry and industry associations. Research is in progress at the U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida, on the development of processed celery products of improved flavor and convenience. Research is also being conducted at the U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas, to develop new and improved processed products from southern grown vegetables other than sweetpotatoes and celery. The Texas Agricultural Experiment Station and industry associations provide raw materials of known history for this research.

Research on new and improved processing technology is conducted at New Orleans, Louisiana, and at the U. S. Food Fermentation Laboratory, Raleigh, North Carolina. Pilot-plant investigations are being carried out at New Orleans to develop new and improved processing methods applicable to commercial manufacture of stable, precooked, dehydrated sweetpotato flakes

from sweetpotatoes of different varieties and environmental history. Processing variables currently being investigated include the effect of variety, curing, type of cooking, drying conditions, and various food additives. Cooperation is maintained with the Marketing Economics Division, ERS, for the market evaluation of improved flake products, and with the Louisiana Agricultural Experiment Station, the Louisiana Sweetpotato Association, the Louisiana Sweetpotato Commission, and various industrial concerns. At Raleigh the objective of the research is to improve pickle processing technology and the quality of the products. Current emphasis is on investigations of methods for the controlled fermentation of cucumbers and other vegetables by application of pure culture techniques to fermentation practices in order to reduce processing costs and improve product characteristics. Limited cooperative work is conducted to evaluate new cucumber varieties (or selections) for processing into brine-cured and fresh-pack products. Cooperation is maintained with the North Carolina Agricultural Experiment Station. The Michigan State University (Department of Microbiology) is also cooperating by providing technical assistance in the controlled fermentation studies. The Pickle Packers International, Inc. contributes support to the research and supplies raw material.

The Federal in-house scientific effort at the Southern Division devoted to research in this area totals 22.1 professional man-years. Of this total 4.5 is devoted to chemical composition and physical properties, 12.1 to new and improved food products, and 5.5 to new and improved processing technology. The domestic grant research involves an additional 0.9 man-year, on chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 56.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Compositions and Physical Properties

1. Identification and Characterization of Flavor and Aroma Components of Pickle Products. A basic study conducted in cooperation with the Pickle Packers International, Inc., and the North Carolina and Michigan Agricultural Experiment Stations has shown much promise in revealing the necessary blends of chemical constituents responsible for both desirable and undesirable organoleptic reactions to fermented pickle flavor. The volatile components have been determined from the pure culture fermentation of brined cucumbers produced by cultures representing four species of lactic acid bacteria (Lactobacillus plantarum, L. brevis, Pedicoccus cerevisiae, and Leuconostoc mesenteroides). Uninoculated natural and pasteurized controls were also analyzed.

The following six compounds were identified from the pure culture fermentations: formaldehyde, acetaldehyde, propionaldehyde, acetone, butyraldehyde, and ethyl alcohol. Two additional compounds were obtained from the natural fermentation (control), namely, ethyl butyrate and isovaleraldehyde. Perhaps the most important contribution of the work to date has been the demonstration that gas chromatography is a useful tool in the study of pure culture vegetable fermentations. Differences in vapor chromatograms were obtained both between species of lactic acid bacteria and between strains of the same species, a finding of vital importance in selecting the most desirable organism for fermentation purposes. The results further indicated that the flavor of fermented pickles is the result of a blend of volatile components rather than the presence or absence of a single component.

Variations in the taste of the vinegar used in the manufacture of commercial pickle products can readily influence their flavor. Research on the volatile components of different vinegars showed marked differences in the number and kinds of components of three natural (cider, wine, and tarragon) and two distilled vinegars. Of 22 different volatile components identified by gas chromatography, 5 were present in all the vinegars and most of the others were present in the natural vinegars, whereas they were strikingly absent from the two distilled vinegars, which had, respectively, only 6 and 11 of these compounds. (S3 5-21).

2. Identification and Characterization of Inhibitor of Enzyme That Softens Cucumbers. Related research being conducted under a new grant to the Research Triangle Institute stems from the observation by Division scientists that the enzyme pectinase, which adversely softens commercial brine-cured cucumbers, can be inhibited by a water extract of muscadine grape leaves (Vitis rotundifolia) or of the forage crop sericea (Lespedeza cuneata). The work is directed toward elucidating the molecular structure and chemical characteristics of this pectinase inhibitor in sericea forage and in other plant sources, the initial step being purification of the active principle from sericea and grape leaves. (S3 5-24(Gr.)).

3. Investigations of the Chemistry and Biochemistry of the Carotenoid Pigments in Vegetables. In cooperation with the North Carolina Agricultural Experiment Station, the chemistry of the carotenoid pigments in vegetables and fruits is being studied in relation to variety, maturity, and environmental factors. The project is founded partially on results of previous investigation of carotenogenesis in grapefruit. The finding that a carotene, contained in a carotene protein complex, stimulates the photo-reduction of ascorbate in the presence of DPN is believed to be the most direct evidence of a function of carotenoids in plant tissue yet found. This protein complex contains carotene hydrocarbons, mono-, and polyhydroxy carotenoids; the relative abundance of carotene hydrocarbons is significantly less than in the intact leaf. Since mixtures of carotenes appear to be inhibitory if the concentration is too high and thus crude preparations are very

concentration-sensitive, progress toward identification has been limited so far to indirect approaches. However, active fractions of a polyhydroxy carotene that is not nearly so concentration-sensitive have recently been obtained. From partition behavior, the active compound appears to be a dihydroxy carotene. An attempt will be made to identify the individual carotenes contributing to the stimulation of the photosynthetic reaction; a mutant tomato high in β -carotene will be fractionated and its precursors compared with those in the red tomato; and an attempt will be made to identify the carotene precursor previously isolated from high lycopene tomatoes. (S3 5-28).

B. New and Improved Food Products

1. New and Improved Dehydrated Sweetpotato Products. Continued work to develop stable sweetpotato flakes from different varieties of sweetpotatoes has revealed that flakes made from apparently comparable, high quality sweetpotatoes in different crop years may differ markedly in shelf-life. In contrast to previous observations, when flakes in an atmosphere of nitrogen containing less than 2% oxygen remained stable for a year or longer, similar flakes made from cured Goldrush sweetpotatoes during 1963-64 had a shelf-life of only three to four months. However, flakes made from the latter lots of roots with the addition of butylated hydroxyanisole, butylated hydroxytoluene, and citric acid were still stable at 10 months. Other research indicates that a good flake product can be made from sweetpotatoes immediately after harvesting by use of any one of three equally effective commercial enzyme preparations. Antioxidant-synergists prolong the shelf-life of these flakes to about the same extent as flakes made from cured roots, but the BHT-BHA-citric acid is still the best known additive for this purpose; no substitute has been found for packaging the flakes in an inert atmosphere. Analytical, viscometric, and enzymatic susceptibility tests indicate that starch changes are not the variable primarily responsible for process or storage differences.

An important result is the discovery of a new amylolytic enzyme having unique properties: its high activity at 65 to 78°C. but low activity at temperatures below 45°C. is highly significant, compared with commonly known amylases. At high temperatures, it has great activity at pH 5.8-6.3 but loses all activity at pH 7.0 and above. Freshly harvested sweetpotatoes contain little of this enzyme, curing does not increase it, but storage at 60°F. results in a progressive rise. This discovery could lead to improved methods of curing sweetpotatoes and also for processing uncured sweetpotatoes, as well as making a significant contribution to enzyme chemistry. (S3 5-25).

2. Development of Processed Celery Products of Improved Flavor and Convenience. Puffed dried celery with commercial possibilities has been developed, and work is continuing to improve its properties, particularly with respect to flavor fortification. Pretreating celery with a calcium chloride solution before blanching or rapid freezing in liquid nitrogen, which eliminates blanching, both promise to improve the texture of the rehydrated product. Color, though primarily dependent on the fresh material, can perhaps be

improved by refinements in drying conditions. More uniform slicing will permit more uniform drying and puffing and therefore improve appearance and rehydration. Development of off-flavor is also being investigated, preliminary results indicating a quantitative difference between the headspace vapors of samples stored at temperatures of -90°, 0°, 40°, and 10°F. Rectification of condensate from steam-distilled celery has been attempted to obtain and concentrate celery flavors. Results from a new larger and longer column show marked improvement in fold and percent recovery. However, more work is necessary to delineate the optimum operating parameters. Processing of 1,400 lbs. of field-run celery showed that 25-30% is left fallow as waste, over half of which shows good potential as a flavor source since it yields almost twice as much flavoring material as the more edible portion of the stalk. The remaining field waste would be of interest for puff dried celery. Among procedures to be attempted in recovering flavoring materials from high-fold essences include adding ethanol either prior to rectification or to the essence after rectification and then freezing the aqueous ethanol solution to remove the water, or using solvent pairs of varying miscibility. Possible changes in relative composition at each stage of recovery will be followed. A revised project will cover phases of the work to be investigated in the near future. (S3 5-23).

3. Development of New and Improved Processed Products from Texas Vegetables. Research is continuing in cooperation with the Texas Agricultural Experiment Station to improve food products processed from southern-grown vegetables, including carrots and tomatoes. Carrot flakes stored for 15 months in an atmosphere of nitrogen have remained the same in ascorbic acid but have decreased slightly in carotene content. Taste tests indicate that flakes packaged in nitrogen and stored at -5°F. may be preferred to those stored at 68°F. Peeling and firming tomatoes in one operation should aid in canning whole tomatoes. The skin of the tomato is ruptured during the blanching operation in a hot, highly concentrated solution of calcium chloride and can be removed by jets of water. Investigations at a canning plant have demonstrated that Chico, LaBonita, Homestead, and M-66 varieties can be thus treated. These four varieties (M-66 added this season) are also being evaluated for the effect of their pectic substances on the consistency of canned juice. Studies of the seasonal variations in Chico tomatoes showed that percent acid and total solids decreased from first harvest (June 17) to last harvest (July 16), whereas pH and Brix remained approximately the same. A major problem is contamination of the calcium chloride peeling solution with tomato pulp; continuing replacement would make the process prohibitively expensive. A lesser problem is the need to find uses for the "tailover" juice made from brokens, pieces, and skins of tomatoes that had passed through the calcium chloride process; its experimental use to cover the calcium-firmed tomatoes when they were canned made them too rubbery and increased the amount of calcium above that permitted by U. S. Standards. Evaluation of new vegetable varieties will continue under this cooperative research. (S3 5-22).

C. New and Improved Processing Technology

1. Development of Processing Methods Applicable to Commercial Production of Dehydrated Sweetpotato Products. Continuing success of sweetpotato flakes is implicit in the interest currently shown by industry. One plant went into commercial production for the 1964-65 season, another expects to be in production this season, and a large food processor is rapidly assembling equipment to make trial runs. Technical assistance has been given to three existing plants, one new plant, and seven prospective plants, and three additional states have requested information. At the same time, research to extend and improve the process is continuing. The effects of drying variables on the rate of drying and on flake quality have been established and made available to the commercial plants.

Further tests of Georgia Red variety sweetpotatoes with additives such as salt, corn syrup, monosodium glutamate, amylolytic enzymes, and various combinations of these agents have not yet produced passable reconstituted flakes, although salt reduced the inherent sour flavor. The light color of these flakes is accounted for by analyses revealing only half as much beta-carotene in Georgia Red as in Goldrush, without color preservatives, the reconstituted flakes and puree discolor rapidly. Flakes prepared this season had a much better taste than those from the 1963-64 crop. Various processing variables have been investigated and a complete material balance conducted on the processing of this variety.

The processing of uncured Goldrush sweetpotatoes has been studied with respect to use of various sugars and use of enzymes. A method of processing uncured sweetpotatoes by utilizing the natural enzymes present in the sweetpotato has been found to produce flakes comparable in quality to those produced by adding commercially prepared enzymes. Optimum conditions of time and temperature have been established. Studies on the Centennial variety have begun, and processing will be extended to include Jersey Orange, Red Velvet, and Julian. (S3 5-25).

2. Investigations to Improve Quality and Reduce Cost of Processed Cucumber and Other Vegetable Products. The groundwork has been laid for the development of a new kind of vegetable fermentation product. A pure culture fermentation process has been described for the controlled fermentation of brined cucumbers. Although many problems must be solved before commercialization of the process, adaptation of a commercial culture medium for the isolation and growth of the fastidious lactic acid bacteria should open the way for the development of improved control and processing methods and for their application in vegetable and other lactic acid fermentation processes. The pure culture fermentation process, developed for cucumbers with the cooperation of the North Carolina and Michigan Agricultural Experiment Stations and Pickle Packers International, Inc., is now being evaluated for use with other vegetables. The pure culture fermentation of green tomatoes, cherry peppers, carrots, and a mixture of these vegetables with cucumbers was the first time this had been done. Pure culture pickles from the four-vegetable mixture were rated as "Good" for overall acceptability; although evaluation of the individual vegetables has not yet been completed, the process appears to offer the

same advantages for them as for cucumbers. Routine testing is also in progress on 100 pure culture fermentations of Spanish-type green olives in brine, into which one of four species or several species mixtures of lactic acid bacteria were inoculated. In addition, 28 lots of pure culture dill pickles evaluated after five months' storage were also rated "Good" by a technical panel composed of pickle plant operators and by a consumer panel. Pickles from naturally fermented controls were rated "Not acceptable." Throughout the past four years, 26 lots of pure culture dill pickles evaluated by 38 consumer panels in several states all rated "Good." Essentially the same evaluation was obtained for pickles inoculated with single species of lactic acid, such as L. plantarum and Ped. cerevisiae, or with a mixture of the two species.

The leaves of sericea forage (Lespedeza cuneata Don) or a freeze-dried extract prepared from it can prevent softening of cucumbers in the presence of pectinolytic and cellulolytic enzymes, an illustration that naturally occurring plant enzyme inhibitors from this or other sources may have application in the fermentation industry. A large amount of fresh sericea has been prepared and sent out for extraction of the purified enzyme inhibitor to be used in further testing. (S3 5-27).

Because of the seasonal nature of the work, during this reporting period there has been no activity in the evaluation of new cucumber lines and varieties for commercial pickling. However, it is anticipated that assistance and supervision will continue to be provided to breeders and pickle packers in cooperation with the North Carolina and Michigan Agricultural Experiment Stations and Pickle Packers International, Inc. (S3 5-22).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

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New and Improved Food Products

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VEGETABLES

Western Utilization Research and Development Division, ARS

Problem. Vegetable crops, in general, are perishable and seasonal and thus are subject to supply and price fluctuations to the disadvantage of the agricultural economy. In order to expand markets and stabilize prices, new and improved processed products are needed that will be more desirable to the domestic and foreign consumer from the standpoint of quality, convenience, stability, nutritive value, safety, and cost. The quality of processed vegetables and the economy of their processing have not improved rapidly enough to increase or even maintain the relative position of vegetables in the American diet, or to increase substantially their contribution to the export trade. The consumption of dry beans and certain other vegetables is limited by the fact that they cause flatulence.

New easy-to-prepare vegetable products are needed, particularly from such commodities as dry beans and peas, which now require hours to prepare. The severe heating required to sterilize low-acid foods, which include most vegetables, seriously impairs the quality of canned products. The stability of all kinds of processed vegetables needs to be improved so that quality and nutritive value will be better preserved during storage and distribution. The safety and effectiveness of new chemical additives, needed to improve the quality and stability of processed vegetables, must be established. Better methods of removing residues of agricultural chemicals from vegetables for processing are urgently needed, as are procedures for decontaminating vegetables exposed to radioactive fallout. Of vital importance is research to reduce the costs of processing in order that the farmer may receive a larger share of the consumer's dollar.

Applied research on these practical problems must be supported by a strong program of basic research on the chemical constituents of vegetables responsible for flavor, color, and texture; on the reactions these compounds undergo before, during, and after processing; on constituents having biological activity; on the microscopic structure of vegetables and vegetable products; and on the micro-organisms which cause spoilage or loss of quality in these products.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, a broad program of basic research on vegetables and the application of science to new and improved products and processes is conducted at the Division headquarters at Albany, California, in field stations at Pasadena, California and Puyallup, Washington; by contract at Urbana, Illinois, East Lansing, Michigan, and Davis and Berkeley, California; by a grant at Urbana, Illinois, and by grants under P.L. 480 in Finland, India, France, and Sweden. Fundamental studies are conducted on the chemistry of vegetable

flavor and vegetable pigments, the mechanism of heat resistance in bacterial spores, the composition of dry beans as related to cooking quality and flatulence-producing characteristics, the factors affecting deterioration of dehydrated vegetables, and the microbiology of raw vegetables for processing. Applied research is conducted to develop new and improved products to increase the utilization of vegetables including new, high quality concentrated and dehydrated products and products of improved convenience of use, processes for producing these, improved freezing methods, selection of improved processing varieties, and methods for removing radioactive fallout.

The Federal program of research in this area totals 33.3 professional man-years, including four scientists whose salaries are provided by the California Lima Bean Advisory Board operating under a State Marketing Order and the United States Brewers Association; and six contracts and grants equivalent to approximately 4.6 professional man-years per year. Of the total, 20.7 are assigned to investigations on chemical composition and physical properties and 12.6 to new and improved food products and processing technology. In addition, the Division sponsors four grants under Public Law 480 on basic research.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 56.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Vegetable Flavor Components. Basic investigations on vegetable flavor are centered on the chemistry of volatile components and include research on tomatoes and onions. In addition, with support of the United States Brewers' Association, which has provided the salaries of two chemists, compositional studies of hop oil are conducted.

In concentrations of about 1 part per million, a few hundred times the olfactory threshold, methyl sulfide contributes to the aroma of canned tomato products. Samples having one-half to one p.p.m. were judged superior to those having lower or higher concentrations. S-methyl methionine sulfonium salt was isolated from fresh tomatoes. The mechanism of its thermal decomposition to yield homoserine and methyl sulfide was confirmed; now it must be considered an important flavor precursor for cooked tomato. Mass spectroscopy has been very useful in identification of extremely dilute organic compounds. A series of butyric and hexanoic esters of 2-, 3-, 4- and 6-carbon alcohols were prepared and tagged with heavy hydrogen. Mass spectral decomposition patterns of the compounds were determined to aid in identification of unknown esters.

An amino acid isolated from dehydrated onions by a collaborator from California State Polytechnic College was found to be propenyl cysteine sulfoxide, which had previously been identified by Nobel Laureate, A. I. Virtanin, a P.L. 480 grantee in Finland. This amino acid is the precursor of the substance in onions that makes us shed tears. It was identified by carbon hydrogen analysis, infrared spectroscopy, specific optical rotation, and isomerization with base to cycloalliin.

Related research on organic components in vegetables and fodder plants is supported by a P.L. 480 grant to Prof. Virtanin at the Biochemical Institute in Helsinki, Finland. Particular attention is given to isolation and identification of sulfur compounds in onions and enzymic and chemical decomposition compounds that have strong flavors or lachrymatory effects.

Our research on hop oil is aimed at isolating and characterizing volatile components that may contribute to flavor of hops. Eighty-seven constituents were separated from the oxygenated fraction of hop oil; forty-two were identified by comparison of mass spectral patterns and gas chromatography retention times with those of authentic samples. Thirty-five other volatiles were detected by their mass spectral patterns and by other analyses. Odor thresholds of 30 major hop oil constituents in water solution were determined. These results were confirmed by preparation of a reconstructed hop oil prepared combining 27 components in the proportions found in natural oil. A number of experienced judges found the mixture was quite similar in aroma to natural oil. A detailed gas chromatographic analysis of 13 American and European hop oils classified them into several rather distinct groups. Such a classification will be valuable to brewers because hop varieties are not readily distinguishable by other methods.

2. Nature of the Heat Resistance of Bacterial Spores. Flavor, color, texture, and nutritional quality of canned vegetables deteriorate under the sterilizing heat requirements necessary to destroy bacterial spores. Year by year the nature of spore heat resistance is being revealed. Although a complete explanation of the mechanism is not yet available, basic observations have taught us how to activate spores or restore them to dormancy and to reversibly control their resistance to heat. These can now be done by chemical means rather than by the use of heat. Spores of B. subtilis were found to have a cation exchange system. The heat resistance of the spores depends on the cations with which they are loaded. When hydrogen ion, for example, replaces calcium in this system, the spores lose resistance to heat. This exchange accounts for the long recognized lability of spores to heat under acid conditions. The heat-sensitive hydrogen form may be made resistant again by loading the spores with calcium again. These simple chemical treatments are similar to regenerating and using a water softener. Another spore phenomenon, heat adaptation or acclimatization, was found. Moderate heating increases the resistance of spores to greater heat when the heat-

sensitive hydrogen form is in a buffered solution of divalent cations. The rate and temperature characteristics of the hydrogen-calcium exchange are similar to the heat adaptation of bacterial spores and may control it. The controlled modifications in heat resistance involve no growing of bacterial cultures. These chemical treatments to effect heat adaptation can be reversibly imposed upon resting spores. Preliminary laboratory studies with vegetable purees have demonstrated the possibility of reducing by 50% the heat treatment required to sterilize products containing large inocula of spores of B. stearothermophilus, B. subtilis, and Clostridium #3679.

Our earlier observations strongly suggest that the heat resistance of spores is related to their density. Neutral lead chelates were prepared in aqueous solutions and used for a density gradient separation of spores. Most of the spore samples used could be separated into more than one band under the density gradient. Separating spores of different density from the same culture appears to be a useful research approach.

A research grant was made to the University of Illinois to provide basic information on the mechanism of spore formation in anaerobic bacteria that spoil food and to develop laboratory techniques for producing plentiful samples of spores of high and uniform heat resistance. Such samples would facilitate research on the heat resistance of spores in canning low-acid foods. The biochemistry and physiology of thermophilic anaerobes is obscure primarily because they are hard to culture. Observations on the mechanism of heat resistance of obligate anaerobes will be compared with the exchangeable cation control of heat resistance that we have discovered with spores of aerobic species.

Investigations supported by a P.L. 480 grant to the National Institute of Agronomic Research in Paris were initiated to identify those enzymes essential for spore germination that are inactivated only by severe heat, and to isolate and characterize these enzymes. Moderate heating of bacterial spores stimulates spore germination but severe heating inhibits it. Metabolic activity during spore germination is under investigation, including the nature and property of enzymes that are involved in spore germination and the exact stage at which the germination of severely heated spores stops. These results will be extended to spores of bacteria that are important in the heat processing of vegetable and other low-acid food products. Others demonstrated that amino acids used during spore germination or vegetative growth are probably metabolized by an amino acid dehydrogenase system which deaminates amino acid. Our grantee in Paris studied the enzyme system involved with material extracted from vegetative cells. Two amino acid dehydrogenases were observed; one was an enzyme not previously described. No apparent correlation was found between the effect of amino acids on spore germination and the properties of these amino acids as substrates for enzyme activity.

3. Composition of Dry Beans. We have reduced the search for the flatulence-producing agent in beans to a fraction which is insoluble in ether, soluble in 60% ethanol, passes with the smaller molecules through a dialysis membrane

into distilled water, remains in solution in 85% ethanol, and is not retained on a cation exchange column. The major flatulence-producing activity is thus in a mixture of low molecular weight compounds constituting about 6% of the initial dry bean solids. In the process of this separation, a way was found to recover from beans more than 80% of their protein in the form of a bland, colorless, flatulence-free powder. Galactose-containing oligosaccharides such as are found in the flatulence-producing fraction increased breath hydrogen, suggesting increased bacterial fermentation in the intestine. The egestion of hydrogen as flatus appears to depend on the subject's respiratory efficiency. Exercise significantly reduced the amount of flatus following a bean meal, probably because of increased ventilation of the lungs. Administration of the drug Vioform, a bactericide, with an experimental bean meal decreased the expected volume of hydrogen, increased the volume of methane, and had little effect on the volume of carbon dioxide in the resulting flatus. Measurements of physiologically inert gases, argon and nitrogen, in flatus by mass spectrometry indicated that nitrogen in flatus arises from swallowed air. In contract work at the University of Illinois experiments are underway with anesthetized dogs. These studies may demonstrate the role of carbonic anhydrase in the transport of carbon dioxide through intestinal walls and inhibition of carbonic anhydrase. However, bicarbonate secretion from the pancreas is not the only source of carbon dioxide of flatus when beans are consumed. Sterilization of the small intestine with antibiotics did not prevent production of gas in that area.

4. Cookability of Beans and Peas. A basic investigation on the influence of phytin on the texture of dry peas during maturation under P.L. 480 at the Fruit and Vegetable Canning and Quick-Freezing Research Association Laboratories at Chipping-Campden in England was concluded. Cooking quality of dry peas is variable; some batches become too soft and others remain very hard after a standard process. Harvesting and drying conditions did not alter the texture of dry peas, but storage at relative humidities over 60% and at temperatures above 70° made dried peas harder to cook. Extensive studies on the phosphorus content and phytic acid of peas indicated that peas with less than 75% of the total phosphorus content as phytate were hard after a normal cooking process, but high phytate content did not guarantee good cooking quality. High calcium in the cell walls of cooked peas correlated closely with toughness; phytin removed calcium by forming insoluble calcium phytates during cooking. However, added phytic acid did not wholly prevent toughening because even in high concentrations of calcium only 60% of the phytate formed complexes. A high phytate content ameliorated the effect of added calcium or magnesium. Storage under unfavorable conditions did not change the distribution of calcium and magnesium in the peas. Textural changes are thought also to be related to modifications in the starch. A decrease in the solubility of starch in perchloric acid and a decrease in starch specific gravity were observed in storage of peas under adverse conditions.

An investigation of the proteins, amino acids, and biologically active components of dry beans was initiated under P.L. 480 at Allahabad University,

Allahabad, India. Procedures for extraction of protein were developed and applied to Phaseolus vulgaris and Phaseolus munga. Semiquantitative fractionation and isolation of proteins from these beans by paper electrophoresis techniques is underway.

5. Vegetable Pigments. A simple microtechnique was developed for the detection, identification, and proof of purity of various chlorophyll components in very dilute extracts from green vegetables. The use of powdered sugar as an adsorbent for thin-layer chromatographic separation of chlorophyll components was an improvement over paper or column chromatographic separations. Chlorophyll degradation products, pheophytin a and pheophytin b, were separated by ascending thin-layer chromatography and could be observed and photographed under ultraviolet light. Fluorescent areas were clearly visible and could be marked, scraped from the plate, and eluted from the sugar for further identification.

6. Histological Studies of Vegetable Tissue. Microscopic studies with green beans indicated that it is possible to freeze beans rapidly enough to prevent visible damage to the tissue and that these beans have firmer texture than those frozen more slowly. Because the usual techniques of the microscopist are too tedious for routine processing control, a new method was developed for examining frozen beans to determine visible tissue damage. Frozen beans to be examined were placed in methanol at about 0° F. Without melting, the water dissolved and was replaced by methanol. Thin slices were then cut across the green bean pods and examined with a 10-power hand lens. By this simple procedure it is possible to discover whether frozen green beans were frozen or thawed too slowly.

Basic investigations on the changing physical characteristics of vegetables during dehydration and rehydration are conducted in contract research at the University of California at Davis. Vegetables representing a range of dehydrating and rehydrating characteristics are under study. Differences in tissue structure were encountered in histological examination of onions, carrots, green beans, celery, green bell peppers, and mushrooms. The experimental approach has been to modify and refine laboratory techniques. Potassium permanganate was superior to other fixing agents for samples to be sectioned for electron microscopy. An epon resin was better than other embedding materials for sectioning samples. The amount of dehydration allowable without significant difference between texture of fresh and reconstituted vegetables varied widely between the vegetables. Enzyme activity in blanched or unblanched dehydrated vegetables was investigated; in unblanched dehydrated onions enzyme activity recommenced during rehydration, even of onions that had been dried well beyond the reconstitution texture-breaking point where irreversible changes must have occurred.

B. New and Improved Products and Processing Technology

1. Dehydrated Vegetables. Research to provide chemical and technological information was initiated by comparing a number of samples of commercially

produced air-dried, unblanched celery with an experimentally produced dried celery. The commercial samples had lost up to a quarter of their original chlorophyll content by conversion to olive-brown pheophytin but the laboratory sample has lost only about half that much chlorophyll. In the laboratory sample, most of the chlorophyll changed during the final drying stages. Higher air temperature in the final stages destroyed more chlorophyll. Gas chromatography determined the loss of volatile components during dehydration. Changes in chromatograms indicated increased formation of several highly volatile components as dehydration proceeded. However, over half of the original amount of several volatiles was lost during dehydration. Reference samples frozen in an air blast freezer also lost large amounts of volatiles. Dehydrated celery rehydrates very incompletely. After drying, cooked celery regains only between a third and a half of its original fresh weight. We have initiated studies to determine if altered processing conditions can improve rehydration.

Studies of foam-mat-dried tomato powder showed losses during long-term storage of lycopene, fructose, glucose, and amino acids to be greater at higher storage temperature. Lycopene is very rapidly destroyed by exposing the dry powder to air. An atmosphere containing less than 0.5% oxygen is needed to retain the red color. Sulfur dioxide treatment before drying stabilized glucose and fructose. Salt increased the loss of all four components. Calcium versenate improved stability somewhat. The most notable change was the disappearance of glutamic acid during warm storage. Interestingly, this amino acid is virtually absent from the more stable foam-mat-dried pineapple and grapefruit products.

2. Dry Bean Products. Development of quick-cooking Lima beans is supported in part by the Lima Bean Advisory Board which provides salaries for two scientists. Dry Lima beans were vacuum hydrated at room temperature in a solution of several salts and dried in low velocity air at moderate temperature and low relative humidity. This treatment reduced rupture of seed coats. Several combinations of salts in solution were tested to reduce cooking time. A combination of four mineral and organic salts was most satisfactory. Following treatment, the dry beans could be cooked in 35 minutes without prior rehydration. Without treatment, the same beans would require overnight soaking and 60 minutes or longer to cook to the same tenderness. The quick-cooking Lima beans have shelf lives equivalent to unprocessed dried Lima beans. Only one of the salts used would require Food and Drug Administration approval and it has already been accepted in other food applications. The treatment was applied successfully to prepare quick-cooking pinto and kidney beans, soybeans, and dry whole peas. Studies on composition differences between unprocessed and quick-cooking Lima beans seek basic information on mechanisms involved.

Drum-dried precooked powders from dried beans, peas, and lentils were developed on a laboratory scale. Scaling-up of such laboratory process to commercial scale depends upon operations, equipment, and cost data not available in the laboratory. Therefore, contract research was initiated at

Michigan State University to carry out pilot-plant development to determine what equipment should be used, how it should be operated, and what the cost of production will be for bean powders. Preliminary studies have been concerned with the adhesion of bean purees to the drying drum. Organic additives were tested, some of which doubled the output rate of the drum dryer. Improved methods for quality control in pilot-plant studies are being developed, including microscopic evaluation of prepared bean powders.

Transfer of energy by microwaves shows some promise for partial drying of cooked beans. Such beans must be air dried to final moisture. By this preparation "butterflying" (curling of the seed coats) is minimized and the product can be readied for serving in 10 minutes.

3. Frozen Vegetables. Basic research on processing frozen vegetables (see paragraph 8-A-6) yielded information on frozen green beans that may immediately change commercial practice. Conventional freezing of green beans on a belt or in a plate freezer damages the tissue by separating cells and rupturing cell walls. Very rapid freezing with liquid nitrogen prevents tissue damage and produces frozen beans that cook to a texture resembling fresh beans. Further studies indicated that total freezing in less than about 15 minutes damages the bean cells very little. Slower freezing causes moderate to extensive damage and results in products that have flaccid texture and sloughing surfaces when cooked. Freezing durations of less than 15 minutes can be achieved in the new fluidized bed freezers and possibly on modified belt freezers. It seems to us that material improvement in the texture of frozen green beans can be achieved with existing commercial equipment. Cooperative work during the next harvest season will test this idea.

4. Processing Quality of Vegetables. Studies on processing characteristics of vegetable varieties are conducted cooperatively with the Washington State Agricultural Experiment Station. Commercial production of asparagus in Washington is increasing and factors such as seasonal variation, cultural treatment, variety, length of green spear, diameter of spear, post-harvest storage, and enzymatic treatments on fiber are under investigation. Samples of canned and frozen asparagus were prepared for organoleptic evaluation and fiber analysis. Irrigation, cultural treatments, blanching, and harvest procedure changed the fiber little, but varietal differences were important in the first year of this study. Five varieties of green beans were evaluated after liquid nitrogen (see paragraph 8-B-3) freezing and conventional freezing techniques. All varieties were firmer when frozen with liquid nitrogen. No differences in firmness were found between midseason and late harvest beans.

In the manufacture of tomato products (puree, paste, catsup, etc.) consistency of the finished product is important and processing variables can materially affect consistency. Consistency is lost by enzyme action when raw tomatoes are broken or crushed before pressing. Heating at the time of crushing to destroy enzymes is common in the industry. Recent data indicate that increases in consistency and better control of consistency may be obtainable through inhibitors of the two enzymes pectin methyl esterase and polygalacturonase.

It is also important in controlling consistency to detect variations in the raw material that will change the product. We have been working cooperatively with a committee of the Canners League of California to develop laboratory methods to make such detections. A test of incoming tomatoes correlated well with finished tomato paste consistency in pilot-scale operation at the University of California, Davis, Department of Food Science and Technology. Further comparative runs will be made during the coming year in pilot-plants, and in limited commercial operations cooperatively with industry groups.

5. Microbiology of Frozen Vegetables. The development of extensive sanitation programs in a number of large food freezing plants is reflected in a general lowering of microbial populations in frozen foods. For several years education and cooperative research have been conducted in the Pacific Northwest to assist in improvement of sanitation in frozen food plants. During the past year, a Department bacteriologist continued his survey of commercial vegetable freezing lines for bacteriological cleanliness. Samples collected from processing equipment showed that coliform bacteria survive and grow on typical machinery used in commercial food processing. Such a finding casts further doubt on the common opinion that all coliforms indicate fecal contamination. It also makes imperative the elimination of slimes from food processing lines. High-level in-plant chlorination will eliminate slimes effectively. Laboratory studies are in progress on growth factors of Pseudomonas aeruginosa, a common contaminant of frozen vegetables. Increased carbon dioxide tension changed metabolism of the organism and the organic acids produced.

6. Removal of Radioactive Fallout. A research contract was initiated with the National Canners Association's Western Laboratory in Berkeley, California to investigate the extent to which external and internal strontium-90 from radioactive fallout can be removed from vegetables and fruits by modification of washing, blanching, and other unit operations of processing. Peas, potatoes, tomatoes, snap beans, spinach, sweet corn, broccoli, peaches, pears, apples, Meyer lemons, and strawberries are being studied. A growth chamber was constructed to keep birds from removing material and to collect radioactive runoff water. Preliminary experiments indicated that all crops in soil enriched to contain over 4,000 p.p.m. of strontium in the top four inches grew abnormally. At 830 p.p.m. of strontium peas, spinach, broccoli, and potatoes grew well. Such culture is necessary to provide material with controlled variable strontium contamination in order to study methods for its removal. Laboratory methods are being developed for the analysis of strontium and of radioactive strontium and cesium in vegetables and fruit.

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POTATOES

Eastern Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, has turned to and is becoming more and more dependent upon the development of new and improved processed products to maintain markets and avoid recurring economic disasters. Crop perishability, fluctuations in supply, and inelasticity of demand, result in wide price swings with even slight surpluses. Depressive lows are moderated by advance contracting by processors prior to harvest in producing areas having a substantial processing industry. However, in many processing areas, processing has not yet been developed and vulnerability still exists and is exaggerated by the growing competition of processed potato and other vegetable food products. If processing is to expand rapidly enough to offset progressive decline in fresh potato consumption, a continuing improvement in currently produced products and development of new products is clearly required.

Lack of adequate knowledge concerning the chemical constituents, physical properties, and enzyme systems in potatoes is limiting development of new and improved products and processing methods. Basic research on composition is needed to provide fundamental information on which an applied research program can be systematically and effectively built. Recently developed techniques make possible the isolation, characterization, and analysis of constituents responsible for flavor, color, odor, and texture of many processed food products which were not available to research in the past. Application of such techniques to potatoes and potato products should make possible the improvement of the quality of present products, both freshly processed and following storage, and provide a basis for technological and engineering studies in new product development.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied chemical and engineering research on studies related to processing. The work of the EURDD, involving the services of chemists, biochemists, food technologists and chemical engineers at Wyndmoor, Pennsylvania, and East Grand Forks, Minnesota, is conducted in cooperation with several Agricultural Experiment Stations which supply potatoes of known cultural history and with the marketing research facilities of the Department. The chemical research program includes: isolation and characterization of the amino acid-sugar intermediate compounds responsible for the browning of chips and French-fried potatoes during processing; studies on lipids, which are believed to play an important role in storage stability of processed potato products, particularly dehydrated products; isolation and characterization of the proteins, which are important from a nutritional aspect and from their possible involvement in textural and processing characteristics; elucidation of the causes of after-cooking discoloration and isolation and characterization of the pigment formed; methods of predicting textural characteristics of potatoes for French-fried potatoes. The Eastern Division's engineering and development research

program seeks to improve the quality, nutritive value and storage stability of dehydrated potato products and to develop more convenient types of dehydrated products, such as "instantized" pieces that rehydrate and cook quickly. The Red River Valley Potato Processing Laboratory, East Grand Forks, Minnesota, has been established to conduct investigations relating variety and other raw material characteristics to quality of established forms of processed potatoes. This Laboratory is operated jointly by the Red River Valley Potato Growers Association, University of Minnesota, North Dakota State University, and the Agricultural Research Service with the Engineer-in-charge reporting to Wyndmoor. The Federal (EU) scientific effort devoted to this area totals 12.4 professional man-years. Of this total, research on chemical composition as related to processing characteristics comprises 9.2 p.m.-y. Research on new and improved processing technology amounts to 3.2 p.m.-y., including 2.0 p.m.-y. for the Red River Valley Processing Laboratory.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations have a continuing long-term program of basic and applied research related to potato utilization. These studies cover the spectrum of problems ranging from the effect on quality of production practices such as variety, fertilization and management, to shelf-life, quality and flavor of processed products.

Mechanical harvesting procedures and storage conditions affect potato composition and in turn suitability for processing. Relating variety, raw material characteristics and storage conditions to quality of the various forms of processed potatoes receives attention at a number of stations. Much effort continues to be given to careful composition studies, particularly those relating to nitrogenous constituents, lipids, amino acids and sugars.

The potato industry is becoming more and more dependent upon development of new and improved products to maintain per capita consumption levels. Product research is directed to solution of problems of texture, sloughing, discoloration and processing procedures such as deep fat frying.

Newer techniques of flavor research are being applied in the search for an understanding of the flavor and flavor changes in potato products. For example, the volatile flavor compounds associated with fresh and stale potato chips are being investigated in order to better understand the changes which occur in these compounds during storage.

The utilization program also includes studies designed to find new and improved uses for sweet potatoes. Studies related to determining suitability for canning, freezing and dehydration are continuing. New research is related to developing improved methods for drum drying sweet potatoes and for drying purees of high solids content. Problems of packaging, additives, storage stability and preparation and use also are under investigation.

The number of professional man-years devoted to potato utilization research is 9.4.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition as Related to Processing.

1. Nitrogenous constituents. Analyses for individual extractable amino acids for the 1961, 1962 and 1963 crop samples of Katahdin, Russet Burbank, Kennebec, Red Pontiac and Cobbler varieties grown in Idaho, Maine, New York, Pennsylvania, Red River Valley, and Wisconsin, have been completed. Statistical analysis for each year and for the three years are now in process in preparation for publication.

Analysis of the 1960 Katahdin crop from Maine and New York has verified the extractable and total nitrogen data obtained with the 1959 crop. Both total nitrogen and extractable nitrogen vary inversely with the total solids when calculated on a dry weight basis. However, on a fresh basis, the amount of nitrogen laid down per gram of tissue is reasonably constant for each individual year. Comparison of the two years, indicates considerable difference in the nitrogen level even though the environmental conditions were remarkably the same. This phase of the experimental work has been completed.

2. Pigments formed during frying of chips. Preliminary studies indicate losses of reducing sugars up to 67% and of amino acids up to 52% when extreme frying conditions are employed. The amino acid-sugar intermediates can be determined by means of the automatic amino acid analyzer. This indicates that ion-exchange methods can be employed for isolating these compounds.

3. Basic studies on potato lipids. Methods have been developed for following the total fatty acid content of potatoes in samples from the raw, immature potato, through processing into flakelets and storage. These include hydrolytic and gas chromatographic methods.

4. Basic studies on the proteins of potatoes. Through gel electrophoretic methods, a minimum of fifteen different proteins are indicated. Comparison of extracts of several varieties indicates little qualitative differences in the proteins but a rather definite difference in the quantitative values. This will aid in selection of varieties for ultimate isolation and characterization of individual proteins.

5. Basic studies on the after-cooking discoloration pigment. Studies on the extraction of the pigment from discolored potatoes have shown an apparent fractionation when progressively increasing concentrations of ethanol are used. It is not yet known whether this is an actual fractionation of different compounds or an apparent fractionation due to solubility. Chromatographic studies are presently in progress.

B. New and Improved Processing Technology.

1. Texture and color of French fries. An objective test, using the Lee-Kramer Automatic Recording Shear Press, is being investigated as a means of predicting quality of the processed product. Work to date has been on

interpretation of the curves produced and relating the pressure changes recorded with the actual events occurring during the shear operation. This work is being done in cooperation with the Horticultural Branch of ARS.

2. New puffing gun design. A gun for the explosion puffing of partially dehydrated fruits and vegetables has been designed. It is also admirably suited to potatoes. Construction drawings have been provided to industry and one company has already received several orders for commercial units. The new gun employs superheated steam in addition to external heat. This results in less heat damage to the product and much higher production rates.

3. New Red River Valley Laboratory in operation. Work is now underway at the Red River Valley Potato Processing Laboratory at East Grand Forks, Minnesota, to determine the effect of variety and cultural practices on the quality of processed potato products. Kennebecs and Pontiacs harvested at two dates, stored and reconditioned have been analyzed for reducing sugars, invertase, pH, phosphorylases, phosphatase and solids content. Pilot plant evaluation of the raw material has thus far been done by conversion to potato chips. The work has not yet progressed sufficiently far to justify conclusions.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition as Related to Processing

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Heisler, E. G., Siciliano, J., Woodward, C. F., and Porter, W. L. 1964. After cooking discoloration of potatoes. Role of the organic acids. *J. Food Sci.* 29, 555-564.

Porter, W. L., Fitzpatrick, T. J., and Talley, E. A. 1964. Studies of the relationship of specific gravity to total solids of potatoes. *Am. Potato J.* 41, 329-336.

Porter, W. L. and Talley, E. A. 1964. Digitizer for application of computers to automatic amino acid analysis. *Anal. Chem.* 36, 1692-1693.

Talley, Eugene A., Fitzpatrick, Thomas J., and Porter, William L. 1964. Chemical composition of potatoes. IV. Relationship of the free amino acid concentrations to specific gravity and storage time. *Am. Potato J.* 41, 357-366.

New and Improved Processing Technology

Heiland, Wolfgang K., and Eskew, Roderick K. 1965. A new gun for explosive puffing of fruits and vegetables. U. S. Agricultural Research Service, ARS-73-47, 7 pp.

POTATOES

Western Utilization Research and Development Division, ARS

Problem. The potato industry, faced with a continuing decline in the consumption of fresh potatoes, is becoming more and more dependent upon the development of new and improved processed products to maintain markets and to avoid recurring economic disasters. Crop perishability, supply fluctuations, and the inelasticity of demand, result in wide swings in price with even slight surpluses. In producing areas having a substantial processing industry, depressive lows are moderated by advance contracting by processors prior to harvest. However, in many important potato growing areas processing has not yet developed, and vulnerability not only still exists, but is exaggerated by the growing competition of processed potato and other competing food products. A continuing improvement in processed potato products is clearly required if processing is to expand fast enough to offset the progressive decline in use of fresh potatoes.

To improve the quality of processed potatoes, ways must be found to eliminate the stale, earthy, rancid, green, and warmed-over flavors that are sometimes encountered in potato products, including dehydrated mashed potatoes, dehydrated diced potatoes, frozen French fries, frozen patties, and potato chips. Equally important, methods must be devised to retain the desirable natural flavor of the freshly cooked potato in the processed product. Recently developed research methods offer an opportunity to isolate and identify the constituents responsible for the natural flavors and the off-flavors, to develop rapid and sensitive analytical methods for their measurement, and to determine the raw material factors controlling formation of the various desirable and undesirable constituents in the fresh potato. Further improvement in the texture of potato products is also needed. Fundamental histological and chemical investigations could be used to determine the causes of differences in the texture of potatoes, as a basis for developing improved processing methods. Enzymes play a great part in the entire compositional pattern of the potato, not only the constituents responsible for flavor, off-flavor, color, and texture, but also those responsible for disorders such as black spot. Black spot causes severe losses both to those who market potatoes fresh, and to those who process potatoes, because trimming costs are sharply increased and yields reduced. Increased knowledge of enzymes is needed as a basis for solution of the black spot and similar problems, to increase use of potatoes by reducing costs, and to improve quality of both fresh and processed potatoes.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, basic and applied research on potato products is conducted at the Division headquarters at Albany, California, and by grant funds under P.L. 480 in

England and Sweden. The chemistry of potato flavor and the compounds involved in deterioration of potato products are studied to provide a basis for new and improved potato processes and products. Histochemical studies are conducted to elucidate factors involved in the texture of potato products. Basic investigations on the enzyme systems involved in potato product discoloration and the mechanism of rancidity development are in progress.

The Federal program of research in this area totals 5.8 professional man-years. Of this number, 3.1 are assigned to chemical composition and physical properties and 2.7 to new and improved products and processing technology. In addition, the Division sponsors two research grants under P.L. 480 on basic studies.

PROGRAM OF STATE EXPERIMENT STATIONS

A report of the State Experiment Station programs appears on page 81.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Flavor Stability. Oxidative deterioration is the predominant storage problem of dehydrated mashed potatoes. Although most food products can be stabilized by refrigeration, oxidation of potato granules and potato flakes continues even at 0° F. Gas liquid chromatography was used to analyze the vapor above reconstituted potato granules after controlled storage tests. Taste panel judgments of flavor correlated well with the hexanal content of the vapor. Deterioration was distinguishable by judges after air-packed granules had been stored three months at 75° F. By that time the hexanal concentration had increased more than tenfold. During the next month, hexanal increased fourfold more. Hexanal appears to be a useful index of oxidative deterioration, but it should not be thought that hexanal is mainly responsible for the characteristic flavor of oxidized granules. Other compounds produced in fatty acid autoxidation almost certainly contribute also.

Basic research on the autoxidation of fats in dehydrated vegetables is conducted under a P.L. 480 grant at the Swedish Institute for Food Preservation Research in Gothenburg, Sweden. Autoxidation can be catalyzed by divalent copper ions. The rate of chemical reaction was measured in model systems consisting of linoleic acid emulsions which were subjected to various conditions of oxygen concentration. Lowering the oxygen concentration reduced the rate of autoxidation, and the reduction was more pronounced in the presence of the copper ions than in the absence of copper. A nearly complete removal of oxygen from the system was necessary to reduce the autoxidation rate by 50%.

2. Enzymic Browning. The nature, distribution, and mode of action of enzymes responsible for browning of potatoes and potato products are studied under P.L. 480 grants at the Low Temperature Research Station in Cambridge, England. Extensive experiments were conducted on the complex influence of soil and climate on browning and tyrosine content of potatoes. (Tyrosine is a component of potatoes that turns to a reddish brown when oxidized under the influence of enzymes.) Urea added as a nitrogen fertilizer increased the amount of tyrosine in potatoes, whereas chloride depressed it. The greater the water content of potato tubers the greater was the concentration of tyrosine. To study the mode of action of phenolase enzyme, it was extracted from the horse bean, a potent source. Comparative studies were made of phenolic substrate biosynthesis in tomato plants, which are closely related to potatoes. The role of minerals in phenolic biosynthesis was mainly an effect on carbohydrate metabolism. Diurnal variations were observed in caffeic acid and sugar concentration in tomato leaves. Caffeic acid increased markedly in the first four hours of darkness and then declined for the rest of the night. During the day, the level either increased or remained constant. Soluble sugar concentration decreased slowly at night, increased sharply during the first two to four hours of light, then decreased during the remainder of the day.

B. New and Improved Products and Processing Technology

1. Effects of Processing on Product Stability. Over 20 years ago, British scientists established that high moisture levels in potato granules retard oxidation, and the addition of sugar to potato granules increases their resistance to browning at high temperatures. We have initiated storage studies of high-moisture (12-13%) granules with sugar added. If the addition of sugar can successfully prevent browning, we may be able to develop dehydrated mashed potato that is stable without gas-packing or antioxidant.

Frozen french fried potatoes for institutional and restaurant use make up one of the largest, if not the largest, of the commercial frozen vegetable packs. This product is widely used in small restaurants without adequate freezer space to hold the potatoes until they are used. We have made bacterial counts and evaluated the flavor, texture, and color of frozen french fried potatoes held at common refrigerator temperatures (34° , 45° , and 55° F.). Off-flavor was detected in about a week at 45° F., and bacterial counts rose substantially. However, no health hazard was indicated. Most of the bacteria were killed in the finish frying, as practiced in restaurants using this product. After four days' storage at 45° F., bacterial counts of commercial samples of frozen french fried potatoes did not exceed 100,000 per gram, a count that is allowed in Canadian regulations for frozen foods and that has been suggested by some health authorities as a suitable standard here.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

Balls, A. K. 1965. Concerning trypsinogen. Proc. Natl. Acad. Sci. 53(2), pp. 392-396.

Burton, H. S., and McWeeny, D. J. 1964. Non-enzymatic browning: Routes to the production of melanoidins from aldoses and amino-compounds. Chem. and Indus. 11, pp. 462-463. 1/

Burton, H. S., McWeeny, D. J., and Biltcliffe, D. O. 1963. Non-enzymic browning: The role of unsaturated carbonyl compounds as intermediates and of SO₂ as an inhibitor of browning. J. Sci. Food Agr. 14(12), pp. 911-920. 1/

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Gumbmann, M. R., and Burr, H. K. 1964. Food flavors and odors. Volatile sulfur compounds in potatoes. J. Agr. Food Chem. 12(5), pp. 404-408.

LeTourneau, D. J., and Zaehringer, M. V. 1965. Constituents of the potato tuber and their relation to texture. University of Idaho Agr. Expt. Sta. Bull. No. 64, pp. 32. (Contract)

Makower, Rachel U. 1964. Effect of nucleotides on enzymic browning in potato slices. Plant Physiol. 39(6), pp. 956-959.

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McWeeny, D. J., Moody, J. P., and Burton, H. S. 1964. The penetration by and distribution of calcium and bisulphite ions during potato scalding and hot-air dehydration. J. Sci. Food Agr. 15(4), pp. 253-258. 1/

New and Improved Products and Processing Technology

Boggs, Mildred M., Buttery, Ron G., Venstrom, Delpha W., and Belote, Mary L. Relation of hexanal in vapor above stored potato granules to subjective flavor estimates. J. Food Sci. 29(4), pp. 487-489.

1/ Research supported by P.L. 480 funds.

Lazar, M. E., Notter, G. K., Smith, G. S., Reeve, R. M., Hendel, C. E., and Morgan, A. I., Jr. 1964. The WRRL direct process for potato granules. Food Technol. 18(7), pp. 1053-1055.

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III. MARKETING AND ECONOMIC RESEARCH

CITRUS AND SUBTROPICAL FRUIT

Market Quality Research Division, ARS

Problem. Research is needed to develop better objective indices for measurement of quality of citrus and other subtropical fruits. This would result in more meaningful grades and standards which could be better enforced. Instrumentation and automatic devices for quality sorting on a commercial basis might be possible. Decays and fruit soilage present serious problems in both domestic and export markets. Much research is needed to relate mechanical harvesting, handling practices, packaging, precooling and transit refrigeration to wastage, and to develop effective treatments for decay reduction. There is need for further research on controlled atmosphere storage for citrus and other subtropical fruits. Problems which are sometimes distinct and sometimes interrelated exist in each of the geographical areas but which require biological research in the separate production areas for solution.

USDA PROGRAM

The Department has a continuing program involving largely applied research performed by horticulturists, plant physiologists, plant pathologists, and food technologists. Research is conducted in the producing areas of California, Florida and Texas. Market studies are made in Belle Mead, New Jersey and Chicago. P.L. 480 grants are operative for research in Colombia on avocado and papaya fruits; for studies in India on identification and mode of infection of fungi causing postharvest rots of tropical fruits; in Spain on detection of additives in citrus juices; in Germany on the antimicrobial action of biphenyl; and in Israel on maturation and ripening of avocados. A contract study on citrus fruit quality as related to mechanical harvesting is under way at the Citrus Experiment Station, Lake Alfred, Florida.

Total federal professional man-years devoted to this area is 11.8. Of this 1.9 is devoted to objective measurement of quality; 1.7 to quality maintenance during handling (mechanical harvesting); 2.5 to quality maintenance in storage; 1.0 to quality maintenance during transportation; 1.0 to postharvest physiology; and 3.7 to postharvest disease control. P.L. 480 projects in this area involve \$64,145 equivalent over a 3-year period in Colombia; \$29,732 equivalent over a 5-year period in India; \$56,163 equivalent over a 4-year period in Spain; \$77,138 equivalent over a 5-year period in West Germany and a 5-year \$83,620 equivalent project in Israel.

Projects terminated during this period included preharvest infection as related to postharvest decay (MQ 2-24) and seasonal changes as related to metabolic activity of oranges (MQ 3-20).

CURRENT PROGRAM OF STATE EXPERIMENT STATIONS

Research on market quality of citrus and subtropical fruit is receiving special attention in three States. California researchers are investigating the effect of storage temperature and length of holding upon the physical and chemical characteristics of citrus fruit. Other research in California is concerned with factors influencing market quality of mature avocado fruits. Research in Florida is designed to determine the relation of physical measurements of citrus fruit to volume of juice and other internal qualities. Florida is also investigating the forced air precooling of citrus fruit.

Fundamental studies on the respiration of papayas and on the browning of lychee pericarp are in progress in Hawaii. These researchers are also interested in factors affecting the keeping quality of Hawaiian fruit in relation to quarantine sterilization. Studies of factors contributing to improved processing and utilization of Macadamia nuts are also receiving attention.

Disease investigations include studies to reduce fruit and vegetable decays during storage, transit, and marketing by postharvest applications of fungicides.

Total market quality research effort on citrus and subtropical fruit at the State stations is approximately 5.7 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Relation of Physical Properties to Market Quality of Oranges and Grapefruit. Light transmittance techniques were found to have good potential for sorting Hamlin oranges for degreening. These readings showed a close relationship between the color of individual fruit and the time required for degreening. Keeping the fruit in the degreening room only long enough to degreen it should reduce rind breakdown and decay during subsequent marketing and permit more efficient use of degreening facilities. (MQ 3-20)
2. Aromatic Polynuclear Hydrocarbons in Citrus Fruits. A method was developed for the cleanup and screening of citrus extracts for residues of polynuclear aromatic hydrocarbons. Benzo(a)pyrene, 3-methylcholanthrene, and dibenz(a,h)anthracene could be detected at concentrations as low as 0.01 ppm. None of the three polynuclear hydrocarbons was found in citrus fruit samples from widely different growing areas or following the usual packing house treatments. (MQ 3-46)
3. Seasonal Changes in Florida Persian Limes. Limes originating from spring blooms developed more rapidly and contained a higher juice content than those from fall blooms. Citric acid content was higher in small limes than in large

ones and was higher in fruits picked during the spring and summer than those picked during the fall and winter. A correlation exists among low juice content, dark green peel, and thick rind. (MQ 3-53)

4. The Detection of Additives in Citrus Juices. Under this P.L. 480 project in Spain a chromatographic method has been developed for detecting synthetic coloring in orange juice that is rapid and practical. Important findings include identification of trace constituents in commercial sucrose and citric acid. This will assist in detecting fraud or excessive additions of these materials to processed orange juice. Progress made in analytical methods also will be helpful in determining composition of unaltered citrus juices. (E25-AMS-6k)

B. Quality maintenance in handling and packaging

1. Citrus Fruit Quality as Related to Mechanical Harvesting. In research underway on contract at the Florida Experiment Station, two methods of mechanical fruit removal are being evaluated for effects on fruit quality, particularly physical damage and postharvest decay. Of the orange varieties tested, the Pineapple sustained the most physical damage and Valencia the least during mechanical shaker harvesting. Fruit removal by high velocity air has caused greater damage than shaker methods so far. Damage by either method has so far been severe enough to prevent their use for fresh market fruit. Limited intramural research in Florida and California has indicated some possibilities for harvesting aids and fruit conveyor systems which increase hand picking speed. Treatment of mechanically injured fruit with approved chemicals has also indicated some promise of holding postharvest decay within commercially acceptable limits. (MQ 2-65)

C. Quality maintenance in storage

1. Controlled Atmosphere Storage of Florida Valencia Oranges. Valencia oranges held for 3 months in CA storage at 32° with 15% O₂ and 0% CO₂, plus 1 week in air at 70° F. had good flavor, were free of rind breakdown, and had the least amount of decay. At 50°, the various controlled atmospheres did not deter development of decay. The respiration rate of the rind of Valencia oranges held for 3 months at 50° F. in less than 1 percent oxygen and carbon dioxide was 10 percent of that of fruit held in air at the same temperature. At 32° in similar CA conditions the rind had a respiration rate of about 30 percent of that of fruit held in air. Under this atmosphere, severe rind browning and excessive decay developed. The respiration rate of the rind of oranges stored at 32° in 15% O₂ - 0% CO₂ was slightly higher than that of fruit stored in air. (MQ 2-110 and MQ 2-79)

2. Controlled Atmosphere Storage of California Oranges. Washington Navel oranges harvested January 11, 1965, were stored 10 to 11 weeks in a number of different CA atmospheres at 36° and 42° F. Five percent carbon dioxide tended to increase the Penicillium decay, especially in fruit held at 36°. None of the fruit in CA had as good flavor as the controls. The flavor tended to worsen with a decrease in oxygen concentration. (MQ 2-98)

3. Controlled Atmosphere Storage of Texas Grapefruit. Two controlled atmospheres, 0.75 and 2.5% oxygen, each with 5% carbon dioxide, were superior to other modified atmospheres or air for control of rind pitting, maintenance of harvesttime peel and pulp color and dessert quality of Texas grapefruit. November-harvested fruit after 16 weeks' storage in either of these two atmospheres, plus 18 days in air at 45°, plus 7 days at 70°, or a total of 20 weeks from harvest, had better external and internal appearance than "tree stored" fruit. Total decay in the early-season fruit held in these two atmospheres amounted to less than 2% after 130 days at 45°. In contrast, January fruit held in similar atmospheres developed 30% decay after only 84 days' storage. (MQ 2-98)

4. Controlled Atmosphere Storage of Florida Avocados, Mangos, and Limes. After 60 days in CA storage at 40° F. Lula avocados were mostly in excellent condition. The most satisfactory atmosphere was 1% O_2 plus 7% CO_2 .

After 6 weeks in CA storage at 55°, Keitt mangos were firm; those stored in air were soft after 2 weeks.

After 30 days in CA storage at 50°, limes were greener and contained less citric acid and juice than those stored in air. (MQ 2-110)

5. Postharvest Changes in Papayas and Avocados. Research on the isolation and purification of avocado oils is continuing under this P.L. 480 project in Colombia but results have not yet been reported. Chemical changes in papayas during maturation indicate a relationship in mature-green fruit between peak concentration of ascorbic acid and maximum difference in concentration of total and reducing sugars. This relationship may prove to be a significant index for determining optimum harvest maturity. (S5-AMS-3(a))

D. Quality maintenance during transportation

1. Thermal Conductivity in Florida Citrus Fruit. Little difference was noted in the thermal conductivity values of Marsh grapefruit harvested in October, January, and May. The mean "k" value for the rind was 1.655 BTU/hr/ft²/°F/in. and for the juice vesicles 3.25 BTU/hr/ft²/°F/in. The diffusivity values of Marsh Seedless grapefruit ranged from .0058 to .0037 sq.ft/hr. (MQ 2-53)

E. Postharvest disease control

1. Control of Decay of California Citrus Fruits. Warm (110° F. or higher) 2,6-dichloro-4-nitroaniline (Botran) solution at 1% concentration and 11.5 to 12.0 pH substantially reduced decay of lemons during storage caused by Penicillium digitatum (green mold) infections. Botran did not control decay quite as well as 0.5% sodium-o-phenylphenate (SOPP) on fruit inoculated before treatment but was better than SOPP on fruit inoculated after treatment. SOPP treatment is not recommended for lemons going into storage at the shipping point because residues in the rind may lead to a build-up of biphenyl-resistant strains of Penicillium. (MQ 2-24)

2. Control of Decay of Florida Citrus Fruit. One percent 2-aminobutane acetate was more effective than SOPP on all varieties of citrus tested. Ten other new fungicides tested were not effective in reducing decay of oranges. Hot water treatment (128° F. - 5 min.) was as good or better than SOPP.

Early harvesting of Robinson tangerines, with extended use of ethylene gas, greatly increased stem-end and side decays.

In simulated mechanical harvesting tests, Hamlin and Pineapple oranges, Dancy tangerines, and Marsh Seedless grapefruit increased in mechanical injury and subsequent decay with increase in maturity, while Valencia oranges decreased. Blossom-end bruising of grapefruit increased from 0 in October to more than 50 percent in May. Prompt use of SOPP effectively reduced the incidence of decay. (MQ 2-65)

3. Materials Affecting Germination and Growth of Decay Organisms. 1,2-cyclohexanediamine tetraacetic acid, a chelating compound effective in binding calcium ions, reduced green mold decay in oranges but not stem-end rot. Extracts of flavedo of oranges induced germination of *Penicillium* spores at a pH range of 2.5-10. Chloride ion and potassium phthalate were inhibitory when added to synthetic medium. (MQ 2-100)

4. Postharvest Diseases of Tropical Fruits. Isolation and identification of causal organisms of diseases of mango, guava, banana, papaya, and sаподilla is being continued under this P.L. 480 project in India. Isolations from harvested fruits and from various plant parts in the field have confirmed earlier evidence that much of the postharvest decay in these fruits is caused by organisms involved in field diseases. Several previously unreported organisms have been identified as causal organisms in postharvest decays. Five well illustrated manuscripts on various findings in this study have been submitted for publication. (A7-AMS-6(k))

5. Antimicrobial Action of Biphenyl. This P.L. 480 project was initiated in Germany during this reporting period. An extensive review of related literature has been completed and research is underway on the effects of biphenyl vapor and solutions on sporulation and growth of *Penicillium* spp. and *Trichoderma lignorum*. (E10-AMS-3)

6. Ethylene Production by *Penicillium digitatum*. The use of sporulating mats in replacement culture studies of ethylene production of *Penicillium digitatum* proved to be a very dependable and convenient technique with low variability between duplicates. Replacement with C (carbon) - free medium of various pH levels gave maximum ethylene production at ca. pH 6. In the presence of a C source (glucose, sucrose, or citric acid), the optimum pH for ethylene production gradually shifted with time from ca. pH 6 to ca. pH 4, the point of maximum growth and respiration. Comparisons of 0.1 M C sources for ethylene production at pH 4 showed that glucose was more effective than citrate, sucrose, glycerol, pyruvate, or malate. The inability of metabolic inhibitors to block ethylene production suggests that *P. digitatum* synthesizes ethylene by several pathways, possibly including the Krebs cycle. (MQ 2-60)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement of Quality

Sanchez, J., Alberola, J. and Garcia, I. 1964. Deteccion de adulteraciones en zumos citricos. II. Identificacion de acidos en variedades de naranjas Agroquimica y Tecnologia de Alimentos 4(3):371. (E25-AMS-6(k))

Quality Maintenance During Transportation

Redit, W. H. 1964. Insulating properties of citrus gift packages exposed to freezing temperatures. The Citrus Industry 45(12):9-11, 13. (MQ 2-53)

Postharvest Disease Control

Hatton, T. T., Jr., and Wm. F. Reeder. 1965. Hot water as a commercial control of mango anthracnose. Proc. Caribbean Region Amer. Soc. Hort. Sci. 8:76-84. (MQ 2-68)

Smoot, John J., and Currie F. Melvin. 1965. Reduction of citrus decay by hot water treatment. Plant Disease Reporter 49:463-467. (MQ 2-65)

Williamson, D. and R. N. Tandon. 1965. Post infection changes in the carbohydrate contents of banana fruits caused by *Botryodiplodia theobromae* Pat. Die Naturwissenschaften 52 Jahrgang Heft 7, S. 166. (A7-AMS-6)

Tandon, R. N., M. P. Srivastava, S. N. Bhargava and A. K. Ghosh. 1965. Studies on fungal diseases of some tropical fruits. V. Some unrecorded fungi. 34th Annual Session on the National Academy of Sciences, India. Section B, pp. 58-59. (A7-AMS-6)

Srivastava, M. P., R. N. Tandon, S. N. Bhargava and A. K. Ghosh. 1965. Studies on fungal diseases of some tropical fruits. III. Some postharvest diseases of mango. Proceedings of the National Academy of Sciences, India. Section B, Vol. XXXV, Part 1, pp. 69-75. (A7-AMS-6)

DECIDUOUS FRUIT AND TREE NUTS

Market Quality Research Division, ARS

Problem. Deciduous fruits and tree nuts are subject to deterioration after harvest through normal metabolic processes and from decay organisms. In addition these products vary widely at harvest in the characters that determine market acceptance. Practical objective measurements of quality would greatly assist in standardization and grading procedures, and the development of instrumentation for this purpose increases the chance for automatic quality sorting on a commercial basis. Additional information is needed on physical and chemical methods for decay reduction and on product quality as related to mechanical harvesting. Research is needed on storage environment as related to temperature, air movement, humidity, atmosphere modifications and fumigants. Continued research is needed with transportation equipment and services as affecting ultimate quality of the product in the market. Dried fruits and tree nuts are subject to insect infestation while drying in the field, during storage while they await processing, in the processing plant, and in marketing channels until they reach the final consumer. Research is needed to develop more effective measures for preventing insect infestation all along this line. Emphasis must be given to finding methods that will avoid both insect contamination and pesticide residues.

USDA PROGRAM

The Department has a long-term program of basic and applied research involving horticulturists, plant physiologists, plant pathologists, and food technologists. The research includes definition, measurement, and maintenance of quality during the period between harvest and consumption. Locations include Beltsville, Maryland; Wenatchee, Washington; Fresno, California; Raleigh, North Carolina; Chicago, Illinois; and Belle Mead, New Jersey. Cooperative agreements and limited contributed funds are in effect with the California Strawberry Advisory Board. P.L. 480 supported research is nearing completion in England on the effects of modified atmospheres on the physiological processes of apples; underway in Finland on fungicide residues and postharvest effects on fruits as related to time and rate of spray application; and in Italy on the principal rots of apples and pears.

There is a continuing program headquartered at Fresno, California, involving applied research in entomology and chemistry, directed toward the prevention of insect infestation in dried fruits and tree nuts. The work is conducted in cooperation with California State and County agencies and with several industry groups. In addition to the direct work at Fresno, much of the cross-commodity research at Savannah, Georgia, reported in Area 13, "Insect Control in Marketing Channels," is also applicable to the problems in dried fruits and tree nuts.

Federal effort in this program totals 17.8 man-years divided as follows: Objective measurement of quality 2.9; quality maintenance in handling and packaging 1.3; quality maintenance in storage 3.7; quality maintenance during transportation 1.5; postharvest physiology 1.4; postharvest disease control 4.0; and prevention of insect infestation 3.0. Research under P.L. 480 includes a 5-year project in England on the biological effects of modified atmospheres for apples at \$67,031 equivalent; a 3-year project in Italy on apple and pear rots for \$18,357 equivalent; and a 5-year project in Finland part of which involves effects of pesticide residues on deciduous fruits at \$96,411 equivalent.

Projects terminated during this period included: Storage of plums (MQ 2-12); controlled atmosphere storage of western apples (MQ 2-57); and the P.L. 480 projects, X-ray research applied to fruit pathology (E15-AMS-4a) and study of pesticide residues (E8-AMS-1).

CURRENT PROGRAM OF STATE EXPERIMENT STATIONS

Numerous projects at the State stations are concerned with research relating to the market quality of deciduous fruit and tree nuts. Such research includes the development and evaluation of equipment and improved methods for the standardization, sizing, packaging, cooling, storage, and handling of fruits; the selection of optimum handling, transportation, and storage techniques for fruit; investigation of the relation of variety, fertilizer, and harvest and storage methods to the quality of fruit; the development of new methods of packaging, and the evaluation of methods of packaging, handling, and marketing individually packaged fruit; the use of spectrophotometric methods to determine market quality and maturity; and fundamental investigations of the physiological and biochemical processes occurring in harvested fruit.

Postharvest research on apples in the Northeastern region is coordinated through the NEM-27 regional project, Post Harvest Physiology of Pomological Fruits. This project is concerned with the development of objective methods of measuring maturity, ripeness, and condition of fruits for fresh market and processing; with the establishment of principles most conducive to maintenance of high quality fruits during the postharvest period; and with the investigation of physiological and biochemical processes occurring in harvested fruit.

Total market quality research on deciduous fruit and tree nuts at the State stations is approximately 38.8 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Eastern Apples. As in 1964, readings with the Magness-Taylor pressure tester and the mechanical thumb differed from each other significantly in certain varieties and the direction of change was not the same for all

varieties. Correlations of fruit firmness judged objectively by inspectors, as compared with mechanical thumb or Magness-Taylor readings, were significant, but .756 was the highest correlation value, which would be fairly poor for prediction. Correlations between mechanical thumb and Magness-Taylor were also significant, but only one of four varieties (Red Delicious) had a predictable value of .8, the others were less than .7.

Correlations of soluble solids and Magness-Taylor or mechanical thumb readings were generally significant, but again the values were not in the predictable range. The computer data are being analyzed. (MQ 3-28)

2. Western Apples. Starking Maturity: After 3 months in storage a significant correlation was found between lower chlorophyll content in the fruit, as measured with the Difference Meter, and greater flesh firmness. In all examinations the soluble solids were lower in fruit with higher chlorophyll content. Organoleptic evaluations after 6 months in storage on fruit harvested at 145 days indicated a preference for fruit with decreased chlorophyll content. Chlorophyll content of all fruit decreased in storage except that harvested 165 days from bloom. Starkings picked at 145 days from bloom had the best dessert quality at all examinations and the fruit harvested at 135 days was superior to that of 155 or 165 days after 5 months in storage.

Red Delicious Sports: Fruit harvested at 138, 147, and 161 days from full bloom from the three spur type trees--Starkrimson, Redspur and Wellspur--were greener fleshed, softer, lower in soluble solids and poorer in dessert quality after 6 months in storage than the Starking strain which was included as a standard.

Other red strains from standard type Delicious trees were comparable to Starking in these evaluations. Scald was more severe on fruit from the 3 spur type trees than that from the other red strains on standard trees.

Golden Delicious Maturity: Soluble solids of fruit picked from 135 to 165 days from bloom were inversely related to the chlorophyll content. Flesh firmness and acidity were similarly related but not to such a striking extent. Dessert quality was directly related to the soluble solids content. Fruit harvested at 145 and 155 days from bloom had the best keeping quality during 7 months of storage.

B-995 as Related to Maturity and Quality: (1) Golden Delicious apples from check trees and trees sprayed in May with B-995 (dimethylaminosuccinamic acid) were separated according to chlorophyll content on the I.Q. Sorter and comparisons were made on fruit of medium chlorophyll content after 3, 5, and 7 months' storage. Fruit from trees treated with 1000 and 2000 ppm B-995 and harvested at 135 and 145 days from bloom was slightly firmer than the controls. Titratable acidity was consistently higher in all fruit from the B-995 treatments. The taste panel preferred fruit from the treated trees. (2) Starking Delicious apples were 1.0 to 1.5 pounds firmer from trees sprayed following bloom with 2000 ppm B-995 than the check fruit but 1000 ppm had no effect on fruit firmness of the 145-day harvest.

Scald was slightly less on apples from the treated trees but commercial control was not approached. The check fruit from all except the last harvest was generally preferred by the taste panel. (MQ 3-28)

3. Red Tart Cherries. In a study of the relation of oxygen concentration in commercial soak tanks to scald symptoms, scald developed in bruised cherries soaked in tanks with low (less than 2 ppm) oxygen. Very little scald occurred in bruised cherries with 2 ppm or more O_2 in the tank. The maintenance of adequate oxygen in the commercial holding tanks appears to provide effective scald control.

Laboratory experiments with bruised cherries in water or in a nitrogen atmosphere showed that the 2 ppm of oxygen can be considered as the critical level for scald development. In these experiments, no scald was observed in bruised cherries held in water with an almost constant oxygen level of 8.6 ppm by aeration at room temperature ($23^\circ C.$).

The anthocyanin pigments in the skin of ripe, fresh red tart cherries were extracted, partially purified and then separated by paper chromatography with various solvents. A total of seven pigments are indicated. (MQ 3-27)

B. Quality maintenance in handling and packaging

1. Film Permeability for Apple Box Liners. Newly developed formulae permit calculation of effective liner areas for design improvement and adjustment of permeability specifications for apples. Defective liner seams and heat seals were greater sources of leaks than pinholes inherent in the film. A simple, rapid, non-destructive test was developed to detect leaks in either empty or filled liners. Formulae were developed to custom-design liners with minimum dimensions permitting cost savings up to 13 percent. In relating respiratory activity to permeability requirements, the initial respiration of size-113 Delicious, Golden Delicious and Stayman apples in air at 30° to $32^\circ F.$ averaged respectively 3.33, 3.73, and 3.57 mg. $CO_2/kg./hr.$ (MQ 2-63)

2. Lenticel Spotting of Golden Delicious Apples. A few lenticel spots developed on Golden Delicious apples exposed to formaldehyde fumes at 250 and 500 ppm, but skin of the fruit discolored in all of the treatments before significant incidence of lenticel spotting. In the previous two years' work with packaging materials having a faint odor of formaldehyde as a result of materials used in formulation, serious spotting occurred without skin discoloration. (MQ 2-72)

3. Blueberries. Wolcott blueberry fruits from 3 harvest dates at each of 2 locations were separated into 8 stages of ripeness based on visual coloration. During ripening the total acidity decreased from 4.0 to 0.5 percent, soluble solids increased from 6.9 to 13.4 percent and anthocyanins increased from 0 to 3 mg per square centimeter of fruit surface. Regardless of location or harvest date, there was a high degree of consistency in sugars, acids, and anthocyanin content for each stage of ripeness and a significant correlation between the

amount of anthocyanin and the ratio of soluble solids to acid which is accepted as a reliable measure of ripeness. Studies are now underway to determine the usefulness of light transmittance for determining anthocyanin content of the berries.

In a large commercial cold storage equipped to employ forced air cooling of the packed blueberries, tests showed half-cooling times of approximately 1 hour, which is in agreement with previous experimental data. (MQ 2-94)

C. Quality maintenance in storage

1. Controlled Atmosphere Effects on Stayman Apples. Stayman apples stored in each of 16 different controlled atmospheres (CA) for 6 months at 32° F. responded much like Red Delicious under similar CA conditions. Fruit from the 1% oxygen atmospheres had fewer external and internal disorders than fruit from atmospheres with either higher (3 or 21%) or lower (near zero) oxygen levels. Firmness and acidity were highest in fruit from the lowest oxygen atmospheres and generally decreased as the oxygen concentration increased. Carbon dioxide production after storage was found to be lowest in fruit from the lowest oxygen levels and increased with increasing oxygen concentrations in the storage atmosphere. A fermented flavor developed in fruit from the lowest oxygen atmospheres. (MQ 2-63)

2. Controlled Atmosphere Storage of Eastern Peaches and Nectarines. Freshly harvested Redhaven and Sunhigh peaches were stored at 32° and 40° F. for 3 weeks in controlled atmospheres (CA) of 1/2, 1, 3, and 21 percent oxygen in combination with zero or 5 percent carbon dioxide and the balance of each atmosphere nitrogen. All of the fruit stored at 32° ripened satisfactorily in air at 60° and there were no appreciable differences in firmness or appearance between peaches in any of the test atmospheres. Peaches from the 1/4 percent oxygen with zero or 5 percent carbon dioxide and those from the 1 percent oxygen with 5 percent carbon dioxide atmospheres ripened in 6 days at 60°, while peaches from the other atmospheres ripened in 4 to 5 days. None of the fruit stored at 40° for 3 weeks in the various atmospheres ripened satisfactorily when transferred to air at 60°. Respiration of peaches in air at 60° was lower for those previously in CA than those in air continuously and also slightly lower in the lots previously stored with 5 percent carbon dioxide than those with 0 percent carbon dioxide. Results with Late Le Grand nectarines were similar to those with peaches. Differences between treatments were slight. A taste panel preferred fruit from storage atmospheres with CO₂ present. (MQ 2-99)

3. Controlled Atmosphere Storage of Western Peaches. Redhaven peaches were held at 31° F. in controlled atmospheres with oxygen at 0.5, 1.0, 2.5, and 5.0 percent, balance nitrogen; carbon dioxide at 2.5, 5.0, and 10.0 percent in air; combinations of 1.0 percent oxygen with the 3 carbon dioxide levels; and air. After 4 weeks, all CA fruit was superior to that in air, which had become dry and mealy. After 6 weeks, the peaches in 1 percent oxygen plus 2.5 and 5.0 percent carbon dioxide were still edible but quality was poor. All other lots were unacceptable. (MQ 2-99)

D. Quality maintenance during transportation

1. Air Shipment of California Strawberries. Precooled strawberries shipped from California to east coast markets by air in June had temperatures of 40° to 54° F. at destination. A partially sealed polyethylene pallet cover and dry ice resulted in a 10% concentration of CO₂ at destination. With the conventional fiberboard sleeve and cap over the pallet, the CO₂ was only 1.7% at destination. After holding there was slightly less decay in the fruit shipped in the polyethylene covered pallet than in that with only a fiberboard cover. Using dry ice without a polyethylene cover appears to be of questionable value. (MQ 2-83)

2. Thermal Conductivity of Apple Tissue. The mean thermal conductivity value for the flesh of Georgia-grown Delicious apples was 2.32 BTU/hr/ft²/°F/in. with a mean moisture content of 84.8 percent. A direct correlation was found between the moisture content and the "k" values. (MQ 2-53)

E. Postharvest physiology

1. Scald Control for Apples and Pears. Dipping eastern-grown Stayman apples for 10 seconds in 2000 ppm diphenylamine (DPA) or 2700 ppm ethoxyquin (Stop Scald) before storage provided excellent scald protection during 5 to 6 months' storage in 4 tests at Beltsville. A 30- or 60-second dip in 130° F. water on either warm (65-70°) or cold (40-45°) Stayman apples also provided very good scald control. A 60-second dip in 120° water was much less effective. Post-harvest dips of 10 seconds in 1% dimethylsulfoxide (DMSO) and 2000 ppm dimethylaminosuccinamic acid (Alar) alone or in combination gave no scald control and the DMSO tainted the fruit. None of these treatments affected fruit firmness or appreciably altered respiration. Ten-second Alar dips at 2000 and 4000 ppm reduced ethylene production at 32° in McIntosh, Rome, Stayman and Arkansas varieties but not in Golden Delicious.

DPA dips and wraps and a combination of dips and wraps controlled scald on western-grown Starkings apples through April but by June scald control was poor in all treatments. Neither ethoxyquin (Stop Scald) nor diphenylamine, dissolved in commercial apple wax preparations at concentrations of 1000, 2000, and 3000 ppm and applied with a commercial waxer to Starkings apples controlled storage scald. Wax alone caused an increase of scald. Wax containing DPA greatly reduced scald on Golden Delicious apples. Ethoxyquin dissolved in commercial wax preparations reduced scald development and skin discoloration from abrasions on Anjou pears. Wax without ethoxyquin did not reduce scald or discoloration. Waxed pears ripened more slowly than unwaxed pears, but they ripened to good quality and had good shelf life. DPA residues in fruit with wax plus DPA were less than 0.5 ppm at 2 months and decreased thereafter. Residues of dip treatments decreased with time, while those on fruit in wraps increased between 2 and 4 months and decreased thereafter. All treatments were well below the DPA residue tolerance. (MQ 2-91)

2. Apple Respiration at Modified Atmospheres. This P.L. 480 study at Ditton Laboratory in England has now been completed. Much basic information has been obtained on the respiratory activity of apples stored in different atmospheres at temperatures from 32° to 54° F. The data indicate increased toxicity of carbon dioxide as oxygen is reduced at low storage temperatures. At 5% oxygen or above respiration was not limited at 32° but at 38° and 45° reduced oxygen concentration limited respiration activity, as compared with air, even at 10 and 15% concentrations. Results with the addition of .05% ethylene to the storage atmosphere confirmed previous findings that it is without effect on respiratory activity at 32° or 38°. Some earlier discrepancies in RQ (portion of CO₂ evolved to O₂ used) seem now to be explained by different peak periods for CO₂ output and O₂ uptake during storage. (E29-AMS-1a)

3. Anjou Pear Scald. This research conducted by the Oregon Agricultural Experiment Station under contract has been completed and a final report submitted. Tests with artificially cooled and heated bearing limbs showed that within the temperatures used susceptibility to scald was not influenced by temperatures during the 2- to 4-week period before harvest. Physiological changes associated with scald development appear to be initiated early in the storage period and were not associated with wax content, volatiles in the cuticle, or changes in specific polyphenols in the epidermal layer. Excellent commercial control of scald was obtained with ethoxyquin either as a prestorage dip at 2700 ppm or incorporated in the widely used copper oil wrap at 2-10 mg per wrap. (MQ 2-66)

4. Effects of Pesticides on Storage Quality. This new P.L. 480 project in Finland is just getting underway. Investigations include the effects of CIPC, IPC and other postharvest fungicides on composition and storage life of tree fruits and berries. (E8-AMS-6a)

F. Postharvest disease control

1. Forecasting Storage Diseases of Apples. Loose fruit of 6 grower lots of Delicious and Winesap apples was washed in a fungicide (sodium-o-phenylphenate) and held at 70° F. in film liners. Packed fruit from the same lots were held in a commercial cold storage room. Apples in the warm room were examined for decay at weekly intervals from 2 through 5 weeks and the fruit in cold storage was examined at monthly intervals from 4 through 7 months. After 3, 4, and 5 weeks in the warm room decay ranged from 3 to 5, 2 to 15, and 4 to 17 percent, respectively. In the cold room there was no decay after 4 and 5 months, but after 6 and 7 months decay ranged from 0 to 2 and 1 to 3 percent, respectively; and a general relationship with the extent of decay at the higher temperature. (MQ 2-67)

2. California Grapes. Hydrocooling reduces the temperature of Emperor grapes very rapidly, improves the appearance of the fruit, and reduces weight loss and desiccation of the stems. Hydrocooled grapes had no more decay after 3 months' storage than grapes that were not hydrocooled, when both were similarly fumigated with SO₂. However, the 1964 season was relatively dry before harvest and tests must be repeated in a wet year.

Fumigation of Emperor grapes as much as 14 hours after inoculation with 1000 to 8000 ppm SO₂ controlled most incipient Botrytis infections at 72° F. As the incubation time before fumigation was increased beyond 14 hours, the infections became increasingly resistant to SO₂. In this experiment, the concentration of SO₂ had little effect. (MQ 2-101)

3. Heat Treatment for Blueberries. Twelve lots of Maryland or New Jersey blueberries were treated for 2 minutes in 125° F. water for 30 minutes in 110° air with 99-100 percent relative humidity. After 2 days at 40° plus 4 days at 70°, postharvest spoilage was reduced from an average 48 percent in dry control lots to 15 percent in hot-water treated lots. Hydrocooling following heat treatment was beneficial when clean water was used but dirty water recontaminated the berries and increased decay. (MQ 2-104)

4. Decay Control for Strawberries. California strawberries heated in a water-saturated atmosphere for 40 to 60 minutes at 111° F. had about 3% decay after 5 days at 37° plus 2 days at 60° F. Untreated lots had about 10% decay. Slight injury occurred in a few replicates heated for 60 minutes, but no injury was found in the 40-minute treatment. A taste panel could detect no differences in flavors or texture between heated and non-heated berries. Gray mold rot of strawberries was effectively reduced in berries held in atmospheres with 0, 1/4, or 1/2% oxygen for 5 days at 37° plus 2 days at 60° F. but 1% oxygen was not effective. Off-flavors in all 4 varieties were always detected in berries held at 0% and 1/4% oxygen. (MQ 2-83)

5. Heat Treatment for Cranberries. A 10-minute dip in 115° water before storage for 3 or 4 months at 38° F. reduced spoilage of cranberries by about 40% from each harvest of 3 Massachusetts bogs. A dip of 2½ minutes in 125° water reduced decay of early-harvested berries and caused little or no injury. Late-harvested berries were injured by this treatment. Late-harvested berries usually had more spoilage than early-harvested berries. (MQ 2-104)

6. Heat Treatment for Peaches. Seven tests were conducted in Fort Valley, Georgia during the 1965 season when incipient infections (pin point rot) prevented the shipment of many peaches. Decay (brown rot) of these peaches during 2 days' holding at shed temperatures was reduced by 84 percent by treating peaches in 127° F. water for 2½ minutes. Peaches heated in 130° water for 3 minutes were no more susceptible to infection by *Monilinia* (brown rot) spores than unheated peaches. Heated peaches were slightly more susceptible to infection by *Rhizopus* (soft rot) spores. Peaches hydrocooled in clear water containing brown rot or soft rot spores and held at 70° F. for 6 days developed about 75 percent more brown rot and 65 percent more soft rot than those hydrocooled in clean water. Addition of 100 ppm of chlorine, as sodium hypochlorite, to the contaminated water reduced both decays by about 60 percent. The amount of free chlorine available from added sodium hypochlorite was found to be related to the amount of organic matter in the water. Organic matter at 0.6 percent reduced available chlorine by about 50 percent after 4 hours. Organic matter at 5.0 percent reduced available chlorine by about 75 percent within a 1/2 hour. (MQ 2-104)

7. Heat Treatment for Figs. Three varieties of fresh figs were heated in water-saturated air at temperatures of 111°, 115°, 118°, 126° and 133° F. for 1 hour. After 5 days at 37°, then 2 or 3 days at 60° surface mold and decay affected 30 to 60% of the untreated figs, but usually affected less than 5% of figs heat-treated at 115° or above. Some inhibition of ripening also occurred at these temperatures, ranging from barely noticeable at 115° and 118° to an objectionable effect at 126° and 133°. (Exploratory)

8. Heat Treatment for Chestnuts. Louisiana chestnuts containing about 51 percent incipient fungus infections were treated with hot water and stored 2 months in perforated polyethylene bags at 40° F. All of the hot water dips greatly reduced decay during storage as compared with the wet and dry checks. Best decay control, without injury, was 1 hour in 125° water. Soaking nuts 15 minutes or longer in water at 140° or higher caused severe injury. (MQ 2-104)

9. Ozone Treatment of Strawberries. Ozone did not reduce rot or extend the market life of strawberries held in high relative humidity at 55-60° F. and ozone at 0.05 to 10 ppm. Shriveling and drying of the cap occurred at concentrations of 0.5 ppm and higher. (MQ 2-102)

10. Effects of Atmosphere Modification on Growth of Certain Fungi. Growth of decay-causing organisms was studied in atmospheres typical of controlled atmosphere storages or nitrogen refrigerated trailers. At a temperature of 15° C., Botrytis cinerea, Cladosporium herbarum, Alternaria sp., and Rhizopus stolonifer grew significantly slower in atmospheres with less than 1% oxygen than in air and were completely inhibited in the absence of oxygen (100% nitrogen). The addition of 15% carbon dioxide to an atmosphere containing 0.5% oxygen reduced the growth rate of these fungi below that at 0.5% oxygen alone. (MQ 2-112)

11. Postharvest Disease Identification. Morphological and physiological studies of a species of Phytophthora isolated from Indiana peaches have shown that the organism is the "parasitica" species.

Morphological, physiological and pathological studies of a disease of California strawberries (not previously reported in the literature) have shown the causal organism to be Phytophthora cactorum. (MQ 2-64)

12. Radiation on Pathogenicity of Fungi. The frequency of both spontaneous and radiation induced sodium orthophenylphenate (SOPP) and sodium dehydroacetate (DHA-S) resistant mutants of Penicillium expansum was studied. In two color auxotrophic mutants, spontaneous resistance was obtained with a frequency of 2 to 3 per 10 million spores. In the normal wild-type, the frequency of SOPP resistance was 35 per 10 million spores. Following radiation which resulted in 97 to 99% kill of conidia, the frequency of both SOPP and DHA-S mutants increased substantially in both mutant and wild-type isolants. Most of the SOPP and DHA-S resistant mutants were avirulent in Jonathan apples. In vitro tests showed all mutants to produce copious amounts of pectolytic enzymes. Avirulence may be associated with permeability changes

to mutant spores. Avirulent mutants of P. italicum and P. digitatum grown with pectin as the carbon source gave filtrates with pectolytic activity. Orange tissue rotted by P. italicum or P. digitatum had both pectolytic and cellulolytic activity; necrotic tissue produced by avirulent mutants of these species had cellulolytic but not pectolytic activity. The pectolytic and cellulolytic enzymes of P. italicum and P. digitatum could be distinguished by their activity curves at different pH values and rates of thermal inactivation. (MQ 2-96)

13. Pesticide Residues. This P.L. 480 project in Finland has been completed and terminated. Nine manuscripts have been prepared on different phases, 3 of which relate to postharvest fungicides. The studies have clearly shown what residues will result from postharvest use of Captan, CIPC, or IPC; what part is removed by simple washing; what part persists through storage or processing; and what degradation products occur. These are helpful data to research people working with the chemicals and to public health agencies concerned with chemical residues. (E8-AMS-1a)

14. Apple and Pear Rots. This P.L. 480 project in Italy is developing much information with useful illustrations, on the rate and nature of growth of Botrytis sp. and Penicillium sp. in apples and pears. Such factors as maturity at harvest, delays before storage and storage temperature are being related to decay development. Further studies are underway on the effect of orchard fertilizers and fungicidal sprays on postharvest decays and work has been started on postharvest treatments for decay reduction. (E15-AMS-2)

15. Proteolytic Enzymes in Relation to Market Quality. Extracts assayed for proteolytic activity were derived from one or more apple, pear, onion, and bean varieties infected with one or more isolates or species of six fungi. The results suggest that proteolytic enzyme activity is not important in decays caused by Botrytis, Monilinia, Neofabrea, or Penicillium. Extracts from apples inoculated with Botryosphaeria and Alternaria produced proteolytic enzyme activity whereas an extract from Anjou pear inoculated with Botryosphaeria was negative.

Extracts from oranges and lemons inoculated with one or more isolates of Alternaria citri, Diplodia natalensis, Penicillium digitatum, P. ultimatum, or Phomopsis citri were prepared to permit confirmation and extension of preliminary assays with citrus. (MQ 2-97)

G. Prevention of insect infestation

1. Improved Pesticidal Control Methods. Malathion dusts were more effective than emulsions when applied at varied dosage rates on raisins or walnuts and almonds in the shell. These were preliminary laboratory evaluations of malathion as a protective treatment, using eggs, larvae, and adults of the Indian-meal moth and the merchant beetle. The treatments were most effective in preventing infestations resulting from introduction of eggs. Larvae were the most resistant stage. Adults of a dermestid beetle, Trogoderma inclusum, were exposed to treated almonds and walnuts and were much more difficult to control than the other two species. (MQ 1-15)

Aerosol applications of dichlorovos in fruit processing plant areas gave good initial kill of Drosophila but no lasting control. Dichlorovos vapor dispensed from a specially designed generator gave excellent initial kill, some mortality into the second day, and reduced populations for 3 or 4 days after the initial application.

Residues were higher in raisins dried on malathion-treated trays during the excellent drying season of 1964 than they were from the rainy drying season of 1963. The previously observed differences in residues in relation to the type of roll used and whether or not the raisins were turned during drying did not show up in 1964. There was, however, a significant difference of 5 ppm between residues in raisins dried on 2 different ranches. (MQ 1-34)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement of Quality

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Postharvest Disease Control

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Stafford, E. M. and A. P. Yerington. 1964. Control of Drosophila in vineyards with insecticidal dusts. *Jour. Econ. Entomol.* 57(6):958-960. (MQ 1-5)

Yerington, A. P. 1965. The use of dichlorvos (DDVP) in wineries for Drosophila control. *Wine Institute Bull.* No. 1307-C. Jan. 25, 1965: (MQ 1-34)

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VEGETABLES

Market Quality Research Division, ARS

Problem. Most fresh vegetables are highly perishable. Research is needed on sources of inoculum and time of infection and physical and chemical methods for decay reduction. Basic studies are needed on cell metabolism as related to the causes and control of functional disorders and the nature of ripening and aging. Product quality as related to mechanical harvesting will need increasing study as will the effects of storage environment on keeping and eating quality. Safe and effective transportation can be accomplished only by continued research with transportation services, equipment, and methods as these affect ultimate quality of the product in the market. The increasing interest in liquid gases for transit refrigeration and atmosphere modification has posed a series of new problems relating to effects on the commodities from release of substantial amounts of nitrogen or carbon dioxide in the load compartments. Additional information is needed on objective indices for harvest maturity and quality factors as related to standardization and grading, and practical measurements for quality changes as the product moves through marketing channels.

USDA PROGRAM

The Department has a continuing program of applied and basic research relating to quality measurement and protection of vegetables as they pass through marketing channels. The work is conducted by horticulturists, plant pathologists, plant physiologists, and food technologists.

Research is conducted at USDA laboratories in Beltsville, Md.; Fresno, Calif.; Miami, Fla.; Orlando, Fla.; Belle Mead, N. J.; Chicago, Ill.; and Harlingen, Texas, and at the North Carolina Agricultural Experiment Station, Raleigh, N. C.

Of the 16.2 federal professional man-years devoted to this program, 2.2 are devoted to objective measurement of quality, 3.5 to quality maintenance in handling and packaging, 0.5 to storage, 3.0 to transportation, 3.0 to post-harvest physiology, and 4.0 to postharvest disease control.

Projects terminated during this period included: modified atmospheres, containers and transit services on asparagus (MQ 2-13); maintaining quality of vine-ripened tomatoes (MQ 2-23); translucent scale of onions in California (MQ 2-56); market quality of western lettuce (MQ 2-58) (related work on lettuce during transit is being conducted under MQ 2-84); market diseases of cucurbits (MQ 2-59); bacterial soft rot of peppers (MQ 2-87); and evaluating quality of tomatoes for processing (MQ 3-15).

CURRENT PROGRAM OF STATE EXPERIMENT STATIONS

Numerous projects at the State stations are concerned with the market quality of vegetables. Research includes studies of methods of cleaning vegetables; studies of methods of quality separation of vegetables; investigations of the effects of transit, storage, prepackaging, and retail handling treatments on market quality; development of packaging methods and materials; studies of senescence and microbe-inhibiting chemicals; hydrocooling; consideration of optimum storage environments including modified atmosphere storage; the investigation of the effect of temperature on the ripening of vegetables; and studies of the influence of storage environment on chemical and physical changes in vegetables. Pathological research involves transit, storage, and market diseases which affect the quality of vegetables.

Total market quality research effort on vegetables at the State stations is approximately 33.1 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Sweetpotatoes. Of 6 varieties harvested at 3 2-week intervals, Copperskin Goldrush had the lowest fiber content and L-9-66 and L-8-92 the highest. Date of harvest seemed to have little consistent effect on fiber content. No relationship could be established between fiber content and shear press peak value of either the raw or canned roots. In 1964 but not in 1963, both reducing sugars and sucrose increased as harvest was delayed. In most cases, curing resulted in an increase in reducing sugars. In 1964, neither curing nor time of harvest seemed to have any consistent effect on carotene content. In 1963, the carotene content increased during curing and roots from the early harvest had lower carotene than those from the midseason or late harvest. Carotene content correlated well with the internal color of the raw, canned, and baked roots. The Hunter a_L value seemed to be the best for estimating carotene content of the roots. Curing resulted in a softer canned Gem in 1964, whereas all 6 varieties were softer when canned after curing in 1963. In 1964 a softer product was obtained as harvest was delayed. The Asco Firmness Index correlated well ($r=0.844$) with subjective ratings but correlated poorly with shear press peak value. (MQ 3-50)

2. Tomatoes. This study of the new USDA tomato inspection procedure was a broad survey of the color of tomato juice from many manufacturing areas of the United States. The relationship of color parameters of processed juice to visual scoring again showed excellent agreement with the Tomato Color Index originally specified for fresh tomato juice. Apparent viscosity and insoluble solids were determined, with wide ranges in readings obtained for these quality factors. Perfect correlation was obtained between the Cal-Lab and Brookfield viscometers. (MQ 3-15)

B. Quality maintenance in handling and packaging

1. Lettuce. Under simulated shipping conditions (8 days at 32°, 37°, or 41° F.) the external appearance of commercially wrapped lettuce was generally slightly better than that of naked heads. In actual shipping tests to the New York market, external appearance was similar in wrapped lettuce and naked heads trimmed after arrival. Discoloration of the cut stem and physical damage were more severe in the naked than in the wrapped pack. Quality loss during a simulated retail period (4 days at 50° F.) was about equal in wrapped and naked lettuce.

Newly received western lettuce and selectively harvested New Jersey and New York lettuce were trimmed and prepackaged in each of 4 different perforated and non-perforated plastic films. They were then held for 4-5 days at 60° F. under relative humidities approximating 50, 70, and 90 percent. Weight losses and decay development during the holding period generally were inversely related. At 50 percent relative humidity, the most decay developed in lettuce prepackaged in the least permeable films, particularly in those lots sprayed with *Botrytis* spore suspensions. Incidence and severity of decay increased as humidity increased; particularly in lettuce wrapped with perforated films. More decay usually developed in lettuce when the film overwrap was heat-shrunk than when it was not. While perforations facilitated water vapor transmission and reduced decay, trimming losses due to wilting frequently exceeded decay losses at the lower humidities. (MQ 2-84)

2. Rhubarb. Rhubarb cut into 10-inch pieces, packaged in perforated polyvinyl chloride film and heat-shrunk had about the same market life (1 day at 70° F. following 5 to 7 days at 32°) as 1-inch stalk pieces in perforated 10-ounce polyethylene bags. Both had better market life than non-packaged controls. (MQ 2-61)

C. Quality maintenance in storage

1. Asparagus Plants. Trimmed (4 to 8 inches from the crown) and untrimmed asparagus plants stored for 3 months at 32° F. in polyethylene and planted immediately after storage did not differ significantly in a 4-year yield test. When stored in burlap bags the 4-inch trimmed plants produced less than those trimmed to 8 inches. Plants stored in burlap lost more weight during storage than those in polyethylene but when held 6 days at 60° after storage and before planting, non-trimmed plants stored in polyethylene had more decay and yielded less than those stored in burlap. Trimming roots before storage reduced the stored weight by 16% for the 8-inch and 40% for the 4-inch trimmed plants. (MQ 2-89)

2. Sweetpotatoes. Isopropyl-N(3-chlorophenyl) carbamate (CIPC) applied as an aerosol for sprout inhibition into the top of a bin of sweetpotatoes stored in bushel baskets caused residue levels to exceed permissible tolerances near the aerosol applicator but provided satisfactory control of sprouting. Application as a fog with commercial equipment gave fairly uniform distribution of

CIPC throughout the roots in palletized field boxes. Residues were within the tolerance but sprouting was reduced only about 50 percent. During 5 months of storage residues decreased approximately 50 percent.

A trench heating system permitted good distribution of heat under stored sweetpotatoes, whether heat was provided with an oil-fired furnace or electric strip heaters. Water added to the trenches maintained a high relative humidity.

Sweetpotatoes lost weight and volume consistently during 35 days at 85° F. with high relative humidity. During storage at 60° F. and high RH loss of weight continued but loss of volume practically ceased. As loss of weight exceeded loss of volume intercellular space increased and the roots became visibly pithy. Intercellular space varied among varieties from approximately 5 to 10 ml. per 100 ml. of root tissue at harvest and varied in its rate of increase during storage. Intercellular space varied less than ± 0.8 ml. per 100 ml. of root tissue for any one variety even though harvested at 3 dates and from 3 locations. (MQ 2-73)

3. Controlled Atmosphere Storage of Cauliflower. Naked and vented film-wrapped Texas-grown cauliflower was stored in controlled atmospheres for 5 weeks at 35° F. in atmospheres of 0.75, 2.5, 5, and 10% oxygen with 5, 10, and 20% CO₂ with each oxygen level; and 10 and 20% carbon dioxide levels corrected daily with air. Comparable samples were held in air. After 5 weeks' storage naked heads showed significantly more weight loss than the wrapped and wrapper leaves were slightly greener on the film-wrapped heads than on the naked heads in 0.75% oxygen, but not at higher oxygen levels. Appearance was maintained best at 0.75, 2.5, or 5% oxygen and in combination with zero, 5, or 10% carbon dioxide. These low oxygen atmospheres did not adversely affect either the uncooked or cooked product. However, the presence of carbon dioxide with 10% or higher oxygen was detrimental to quality. Tests will be continued.

Controlled laboratory tests in California verified results reported last year of injury to cauliflower commercially wrapped in unperforated films. Holding cauliflower at a higher temperature (41° F.) and for shorter periods (1 week) than in the Texas tests in 5, 10, or 15% CO₂ with 15, 10, and 5% O₂ respectively, resulted in an undesirable grey and soft curd when cooked. Appearance ratings were substantiated by reflectance and shear-press measurements. The effects of high CO₂ were not apparent on raw cauliflower and diminished after removal from the modified atmosphere. Low oxygen (1, 5, or 10%) had no adverse effect on color or texture of cauliflower in the absence of CO₂ during 7 days at 41°. However, some tasters noted an off-flavor in curds held in 1% oxygen. (MQ 2-71)

4. Symptoms of Freezing Injury. Symptoms of freezing injury of carrots after thawing included: blackening, watersoaking, cracking, and pitting. Blackening increased with the severity of the freezing, regardless of the thawing temperature. Pitting was more severe in carrots thawed at 70° F. than in those thawed

at 40° but lightly frozen carrots thawed with much less total damage at 70° than at 40°. Cracking and watersoaking were present only in carrots frozen 4 hours or more at 20° or below.

Peppers lightly frozen recovered with less damage at 40° than at 70° F. After being frozen 1/2 hour at 20°, 82% of the peppers held at 40° thawed with no visible damage. When thawed at 70°, only 50% recovered. When the peppers were frozen severely, the damage after thawing was about equal at both temperatures. Decay, watersoaking, shrivelling and pitting were freeze symptoms. (MQ 2-29)

D. Quality maintenance during transportation

1. Asparagus. Asparagus spears were held for 24 hours in 20 or 30% CO₂ plus 6 days in air at 36° or 41° F. to simulate transcontinental shipment. Soft rot of the cut ends after the period at low temperature and after 3 more days at 59° F. was significantly reduced by CO₂ treatment. Soft rot of the tip ends was not reduced by these treatments. When the CO₂ concentration was brought initially to 20% and reduced 1/2 every 15 or 30 hours during 7 days' holding, soft rot was reduced and overall quality was better than the controls held in air. An initial 30% concentration of CO₂ injured the spears. There was no impairment of flavor with either treatment. Spears with relatively open tips developed more soft rot than spears with tight tips although both tip conditions were in the range found commercially. Asparagus held 6 days at 40° remained in good condition when stored in air or in an atmosphere of 3% oxygen and 97% nitrogen. Off-flavors developed in 100% nitrogen. Respiration at 40° was about 30% lower in the low-oxygen atmospheres than in air but the reduced rate was not related to extended storage life. (MQ 2-13)

2. Lettuce. New Jersey lettuce held 4 weeks at 33° F. at 3 different modified atmospheres was in better condition, on removal, than lettuce held in air. When held an additional 3 days at 50° in air, only the lettuce held in 0% CO₂ and 1.8% O₂ remained better. The appearance of the lettuce from the atmospheres containing 3.5 to 7.0% CO₂ deteriorated rapidly because of a tan or bronze discoloration on all leaves.

California lettuce kept better in an atmosphere of zero CO₂ and 6% O₂ than in air, but 10% CO₂ and 10% O₂ was undesirable. After six weeks at 33° F. in the respective atmospheres, followed by 2 days at 45° in air, 88% of the lettuce held in zero CO₂ and 6% O₂ remained edible as compared to 32% edible in air whereas lettuce from 10% CO₂ and 10% O₂ was unusable because of the serious discoloration.

Temperatures in test shipments made in liquid nitrogen-refrigerated trailers averaged 3 to 5° F. warmer than those in trailers with mechanical refrigeration. Temperatures within the load in nitrogen trailers varied as much as 12° F. and were sometimes as high as 50° to 60° at destination. Oxygen levels in the nitrogen trailers were generally above 1% but in some test shipments, levels below 0.5% were found. In a few trailers CO₂ accumulated to more than 5%.

Less russet spotting generally developed in lettuce from the nitrogen trailers than in that from trailers with only mechanical refrigeration, but significant reductions were found only in lots having high susceptibility to this disorder. Decay was worse in lettuce from the nitrogen trailers than in that from the better refrigerated mechanical units.

Lettuce held without oxygen for 7 days at 36°, 41°, or 50° F. was severely injured; that held in 0.25% oxygen was moderately injured and had off-flavors; that held in 0.5% oxygen was occasionally injured; but lettuce held in 1% or 2% oxygen was not injured. Less pink rib and butt discoloration occurred in lettuce held in 1% or 2% oxygen at 36° or 41°. Russet spotting was reduced from 30% (in air) to 5% when susceptible lots were held in 1% or 2% oxygen. (MQ 2-71 and MQ 2-84)

E. Postharvest physiology

1. Treatment of Asparagus with a Growth Retardant. Dipping the basal ends of freshly harvested asparagus spears for 1 hour in 1000 or 2000 ppm of dimethyl-aminosuccinamic acid (Alar) reduced respiration 10 to 15 percent below that of non-treated asparagus. However this growth retardant had no apparent effect on weight loss, spear elongation, green color or decay after 3 or 5 days at 70° F. (MQ 2-61)

F. Postharvest disease control

1. Onions. About one hour after the necks of freshly harvested onions were sprayed with a Botrytis allii spore suspension, they were dusted with various dessicants and fungicides to seal the wounded necks from infection by neck rot. After 4 months in common storage, decay was reduced from 100% in the inoculated untreated lot to 45% in the inoculated Botran- and Calcium chloride-treated lots; and from 5% to about 3% in the non-inoculated lots. The other 14 treatments were less effective. In other tests, freshly harvested and topped onions flamed at the cut region were inoculated with either Botrytis allii spore suspensions, or by dusting with soil from a farm with a history of Botrytis neck rot. After 4 months in common storage flaming resulted only in a slight reduction of decay on some of the lots treated with Botrytis suspensions. When onions infected with soil borne Botrytis were subjected to flaming, the non-flamed lots averaged about 9 percent decay, the flamed lots 3 percent. (MQ 2-95)

2. Soft Rot in Bell Peppers. Peppers from two South Texas fields showed differences in susceptibility to bacterial soft rot after passage through a contaminated brush-waxer unit; and the degree of decay control obtained with hot water (128° F. for 1.5 minutes) after artificial inoculation. Pod stems with the highest dry weight developed the least infections and responded best to decay control treatment. The main source of soft rot infection in the packing shed was the brush-waxer unit. The development of soft rot was more than four times greater in peppers collected after passage through the brush-waxer than in peppers collected before. Contamination of the brush-waxer with

soft rot inoculum was largely responsible rather than the wax itself. Spraying the waxer with strong chlorine solution did not always eliminate the inoculum.

Botrytis spores which were brushed on wound-free areas of pepper pods germinated in 4 days at 55° F. with high RH and caused death in small areas of surface tissue producing a speckled appearance on the pod. Generally, the germinating spores did not penetrate the epidermis, but the spores remained alive for 2 or 3 weeks on the surface. The adverse effect of chilling was demonstrated by holding pods at 32° F. for 0, 4, 8, 12, 16, and 20 days and inoculating with gray mold just before they were shifted to 55°. After 14 days at 55° the decay increased with each increase in the prior period at 32°. The results showed that high relative humidity and low temperature injury are the dominant factors in the predisposition of peppers to natural infection by Botrytis cinerea, the cause of gray mold of peppers. This project has been completed and a manuscript is under preparation. (MQ 2-87 and MQ 2-52)

3. Sweetpotatoes. Treatments with hot water, sodium-o-phenylphenate (SOPP) or 2,6 dichloro-4-nitroaniline (Botran) failed to control decay of sweetpotatoes damaged by wet soil. Control of soft rot (*Rhizopus* sp.) and charcoal rot (*Sclerotium bataticola*) was obtained in normal roots with either chemical but surface and end rots (*Fusarium* sp.) were not controlled.

Polymethylgalacturonase and macerating enzyme activity can be demonstrated in the juices obtained from autoclaved sweetpotatoes upon which Rhizopus stolonifer has grown but no pectinmethyllesterase (PME) activity can be detected. In the juices obtained from salt extracted frozen and thawed sweetpotatoes, only PME activity is detectable. The juices expressed from *Rhizopus*-rotted sweetpotatoes contain all three enzymes. The evidence suggests that PME is produced by the host and not, as is reported in the literature, by the pathogen. (MQ 2-73 and MQ 2-60)

4. Tomatoes. Mature-green tomatoes of Manapal variety were found to be more susceptible to postharvest decay by *Alternaria tenuis* than tomatoes of the W. R. Grothen Globe variety. Tomatoes of the Manapal variety were affected more by chilling, either while on the vine or after harvest, than Grothen Globe.

A disorder, in increasing amounts, has been noted on California and Mexican cherry tomatoes. The disease is characterized by a superficial stain, often seen in fine lines that radiate along sides of fruits. Isolations have yielded principally *Alternaria*, *Stemphyllium* and occasionally *Cladosporium* spp. (MQ 2-88 and MQ 2-64)

5. Lettuce. Lettuce held in 1 ppm of ozone for 3 days at 36° F. and high relative humidity was severely injured. The distal portions of the outer leaves were flaccid, water-soaked, and transparent. The exposed midribs showed rusty-brown flecks. The normal green color of the chlorophyll-containing tissue was changed to a pale yellow.

Lettuce affected by "speckles" (a field virus disorder) was inferior in appearance to normal lettuce after 7 days at 41° F. and after 4 additional days at 50°. At the second examination russet spotting, pink rib, decay and total defects were more prevalent in the virus infected than in the apparently healthy lettuce.

A fungal decay of head lettuce by an *Alternaria* species was found in a rail shipment from Arizona. The decay, frequently associated with bacterial soft rot, was also noted in some test shipments of western lettuce. Pathogenicity studies indicated the fungus is a weak pathogen whose virulence on lettuce appears dependent on a saprophytic start in dead tissue. (MQ 2-102 and MQ 2-64)

6. Cantaloupes. A soft, watery, stem-end decay of California and Mexican cantaloupes caused by the fungus, Geotrichum candidum, was noted on the New York market during the past year. Decay incidences of 1 to 16 percent were found in a few rail shipments on arrival. An isolated case of the decay on a honeydew melon from California was also found. There appears to be no previous record of its occurrence on the market. (MQ 2-64)

7. Effects of Chlorine on a Vegetable Decay Organism. Exposure time had a greater influence than temperature or pH on the activity of chlorine against Alternaria tenuis spores. Even at 36° F. and pH 8, an effective kill was obtained when the spores were exposed to 5 ppm chlorine for 30 minutes. Raising temperature from 50° to 68° increased spore kill, but a rise from 36° to 50° had little effect. A greater spore kill was obtained with 3 ppm chlorine at pH 6, 7, or 7.5 than with 5 ppm chlorine at pH 8. (MQ 2-116)

8. Effects of Modified Atmospheres on Growth of the Soft Rot Bacterium. The soft rot bacterium, Erwinia carotovora grew faster at 59° F. when carbon dioxide (5, 10, or 15%) was used in combination with a 0.5% oxygen concentration than when the low oxygen was used without CO₂. When the bacterium was incubated for 24 hours in air at 59°, differences in growth due to prior exposure to controlled atmospheres disappeared. (MQ 2-112)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance in Handling and Packaging

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Johnson, Robert M. 1964. Maintenance of dry bean quality during transportation, handling, and storage. Proceedings for the 7th Dry Bean Research Conference, Ithaca, New York. (MQ 2-30)

Quality Maintenance During Storage

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Kushman, L. J. and M. W. Hoover. 1965. The influence of chilling temperature upon acidity of Goldrush sweetpotato roots and flakes made from them. (Abstr.) Proc. Assoc. Southern Agr. Workers Inc. 62:188-189. (MQ 2-73)

Ritchie, R. M., Jr., F. S. Wright, and L. J. Kushman. 1965. Pallets for sweetpotato field crates. N. C. Agr. Expt. Sta. EAE Inf. Ser. No. 365. (MQ 2-73)

Kushman, L. J. and F. S. Wright. 1965. Overhead ventilation of sweetpotato storage rooms. N. C. Agr. Expt. Sta. Tech. Bul. 166. (MQ 2-73)

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Kushman, L. J. and D. T. Pope. 1965. Preliminary report of the estimation of intercellular space in sweetpotato roots and its relation to pithiness and specific gravity. (Abstr.) Proc. Assoc. Southern Agr. Workers Inc. 62:189. (MQ 2-73)

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Harvey, J. M. 1965. Nitrogen--its strategic role in produce freshness. Produce Marketing 8(7):17-18. (MQ 2-84)

Postharvest Physiology

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Parsons, C. S., J. E. Gates, and D. H. Spalding. 1964. Quality of some fruits and vegetables after holding in nitrogen atmospheres. Proc. Amer. Soc. Hort. Sci. 84:549-556. (MQ 2-71)

Postharvest Disease Control

Kushman, L. J., W. R. Wright, J. Kaufman and R. E. Hardenburg. 1965.
Fungicidal treatments and shipping practices for controlling decay of
sweetpotatoes during marketing. U. S. Dept. Agr. Mktg. Res. Rept. 698.
(MQ 2-73)

Wright, W. R., M. A. Smith and L. Beraha. 1964. Sour rot of carrots.
Plant Dis. Rptr. 48:837-838. (MQ 2-64)

POTATOES

Market Quality Research Division, ARS

Problem. The many varieties of potatoes, the different areas of production and seasons of harvest and special storage and handling requirements for specific uses require a continuing program of research on handling, storage, transportation, physiology, wastage control and quality measurement. The increased demand for potatoes to be used for chips, frozen french fries and other processed forms has created special problems to prevent undesirable chemical changes due to low temperatures during storage and transport. The use of higher temperatures has brought on additional problems of moisture loss and of bacterial and fungal decay. Higher temperature storage also calls for control of sprouting, with increased emphasis on sprout inhibitors. Objective indices are needed to identify quality factors that are important for specific product usage and relate measurable characters of the raw product to quality of the processed product. Also needed are instruments for non-destructive detection and rejection of potatoes with internal disorders during grading.

USDA PROGRAM

The Department has a long-term program involving horticulturists, plant pathologists and plant physiologists engaged in applied and basic research. The work at East Grand Forks, Minnesota, is conducted in cooperation with the Minnesota and North Dakota Agricultural Experiment Stations and the Red River Valley Potato Growers Association. The work at Presque Isle, Maine, is in cooperation with the Maine Agricultural Experiment Station. Research on transportation of early potatoes for chips is conducted by the Fresno, California station. The studies at Beltsville involve quality evaluation, sprout inhibitors and basic research. Studies on market diseases are conducted at Chicago and Belle Mead, New Jersey.

The Federal scientific effort devoted to research in this area totals 5.5 professional man years. Of this number 1.0 is devoted to objective measurement of quality, 0.5 to handling and packaging, 1.5 to storage, 0.5 to quality maintenance during transportation, 0.5 to postharvest physiology, and 1.5 to postharvest disease control.

Projects terminated during this period included: chemicals for control of sprouting. (MQ 2-31).

CURRENT PROGRAM OF STATE EXPERIMENT STATIONS

Market quality research on potatoes at the State stations is concerned with maintaining potato quality through the harvesting - storing - marketing process. Factors of potato storage such as volume of air and fan operation required to maintain a specific temperature; optimum ventilating time; effect of various storage temperatures on sprouting, specific gravity, and rotting; and the use of various sprout inhibitors are being investigated. Efforts are being made to develop and standardize a reliable objective method for evaluating potato texture, and to apply this in determining the effect of extended storage practices on textural quality of potatoes. Research is underway to design and evaluate instrumentation for sensing and controlling the concentration of O₂ and CO₂ in storage houses.

Fundamental studies include investigations of the biochemical and physiological factors which precondition tubers to different types of internal and external mechanical injury. Tuber respiration studies are designed to determine the effect of temperature and length of storage on chip color and quality of potatoes.

Disease investigations involve studies of potato scab, bacterial ring rot, other bacterial and fungal diseases, identification and control of potato virus diseases, and determination of the effect of such diseases on market quality.

Total market quality research effort on potatoes at the State stations is approximately 5.6 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement of quality

1. Predetermining Processed Quality in Potatoes. Research relating characteristics of the raw product to quality, particularly texture of frozen french fries was conducted in cooperation with the Eastern Utilization Research Division. Thus far no relationship can be established between shear press readings of the raw, par fried, or reheated strips with textures of french fries as evaluated by a taste panel. (MQ 3-56)
2. Susceptibility of Tubers to Bruise Damage. Tests were made with an impact instrument to measure susceptibility of several Red River Valley potato varieties to injury at different stages of maturity. The index obtained with this instrument was reasonably well related to the actual damage during harvesting. (MQ 3-40)

Maine potatoes decreased in resistance to bruising from harvest through 20 weeks' storage, then increased in resistance through May. Other tests showed that tubers increase in resistance to bruising during the first hour when moved from 45° F. to 60°. (MQ 3-40)

B. Quality maintenance in handling and packaging

1. Mechanical Injury Incident to Sizing Potatoes into Storage. Damage and skinning of Red Pontiac potatoes increased slightly but consistently during sizing into storage. The dimensional shrink of tubers after about 6 months' storage was reasonably consistent over the 3 dimensions measured except when pressure bruises occurred. (MQ 2-78)
2. Stone Separation. Moving water was found to be an effective means of separating stones from B-size seed stock. Fluming, shipping, and field tests indicate that water had no detrimental effect on the quality of the seed with respect to breakdown in transit, disease development in the field, or yield. (MQ 2-93)

C. Quality maintenance in storage

1. Storage Temperature on Processing Quality. Effects of storage temperature on the processing quality of six potato varieties were determined at East Grand Forks. Continuous storage at 50° F. generally gave lighter flake color with less tendency to greying in some varieties than when the potatoes were stored at 40 or 45° followed by conditioning at 65°. Flakes of the Norgold Russet had some undesirable texture characteristics after storage of the potatoes at 40°. Only Kennebec and Irish Cobbler made acceptable chips and french fries, with some variation with storage temperatures; Bounty, Snowflake, Red Pontiac and Norgold Russet were unacceptable for these purposes. (MQ 2-69)
2. Methods and Rates of Ventilation on Quality of Maine Potatoes. Fusarium tuber rot, Verticillium -pinkeye rot, and soft rot were controlled with ventilation in both 38° F. and 45° F. bin storage and pallet box storage at 40°, 45°, and 50° F. However, pressure bruising and internal black spot were severe in the 45° F. bin storage and tended to increase in severity as the airflow rates were increased from 0 to 1.8 cfm/cwt. Weight loss during the storage period ranged from 3.8% in 0 cfm/cwt. to 5.3% at 1.8 cfm/cwt. at 38°. (MQ 2-92)
3. Control of Sprouting of Potatoes. At Beltsville, potatoes dipped in solutions of CIPC ranging from 0.10 to 0.25% were free of external and internal sprouts after 4 months' storage in ventilated drums at 61° F. Those dipped in concentrations ranging from 0.000005 to 0.05% developed appressed external sprouts and some internal sprouts. Untreated potatoes, not in the drums but in the same room, had fairly normal external sprouts and no internal sprouts. The growth retardant dimethylaminosuccinamic acid (Alar) used as a 30 - second dip at 2000 ppm on Katahdin potatoes before storage did

not reduce sprouting.

In Maine, potatoes treated with a 5% dust formulation of CIPC as they were placed in storage had about 1½ times as much decay and were considerably duller after washing than untreated potatoes. Much of the dullness of the treated potatoes was due to silver scurf.

Casoron (2, 6-dichlorobenzonitrile) at rates as low as 4 ppm gave good inhibition of sprouting on Kennebec, Pontiac and Norgold varieties stored in the Red River Valley. Casoron appeared to be more effective at 65°F. than at 55°. (MQ 2-31)

4. Storage in Modified Atmospheres. Potatoes stored in 95% carbon dioxide and 5% oxygen developed extensive black heart and breakdown within 50 days at 40° and 55° F. Those stored in 99% nitrogen and 1% oxygen had only a trace of black heart at 40° but large amounts at 55°. Potatoes stored in 5 and 10% oxygen, the rest of the atmosphere nitrogen, and those stored in air did not differ significantly in appearance or in color of chips produced after 100 days' storage. (MQ 2-71)

D. Quality maintenance during transportation

1. Transit Temperatures of California Potatoes. Potatoes harvested May 5th produced relatively dark colored chips after holding at several simulated transit temperatures from 50° F. to 75° for 5 or 9 days. Chip color was best in potatoes held continuously at 70° and 75° F. The relatively dark color of the chips produced from all these potatoes probably resulted from low preharvest air temperatures, which averaged 58° F. during the week before digging. Potatoes harvested May 19th and June 23rd produced chips of acceptable color when held for similar periods at temperatures as low as 50°. However, those held at 60° or warmer produced the lightest colored chips. Generally potatoes held at low temperature could not be reconditioned by holding an additional 4 days at 75° F. (MQ 2-55)

2. Heavy Loads of Maine Potatoes. A comparison was made between 50,000- and 60,000-pound rail carloads shipped in the fall under ventilation, in the winter under heater service, and in the spring under ice-refrigeration. No significant difference between loads was found in bruising or disease development in transit. This research has been completed and a manuscript has been prepared for publication as a Maine Agricultural Experiment Station Bulletin. (MQ 2-42)

E. Postharvest disease control

1. Prestorage Washing. Two experimental materials and a 5-minute water dip at 130° F. applied at harvest satisfactorily controlled lenticel infection which is a problem in prestorage washing. These materials and a 7-minute water dip at 130° F. were also effective when applied 1 month after harvest. (MQ 2-93)

2. Hot Water Treatment of Seed Potatoes. Whole B-size seed of three varieties dipped for 3 minutes at 130° F. were not adversely affected in transit or in the field, confirming previous results. Seed tubers infected with the new strain of Streptomyces scabies, dipped for 5 minutes at 130° F. produced tubers with less scab than untreated controls. Dipping tubers in 130° F. water for 7 minutes reduced silver scurf development in storage. A 5- or 7-minute dip at 130° F. before storage also gave satisfactory control of bacterial lenticel infection and produced potatoes that were bright after storage. (MQ 2-90)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance in Handling and Packaging

Hunter, J. H., J. B. Wilson, and J. C. Thibodeau. 1964. A Forklift Mounted Scoop for Bulk Potatoes. Maine Agr. Exp. Sta. Misc. Pub. 622. (MQ 2-93).

Wilson, J. B., J. H. Hunter, and M. E. Gallegly. 1965. Stone Separation in B-size Seed Potato Stock. Maine Farm Res. 12(4):10-15. (MQ 2-93).

Quality Maintenance in Storage

Akeley, R. V., Audia, W. V. and P. H. Heinze. 1965. Some Newer Potato Varieties and Their Chipping Qualities. Proc. Production and Technical Div. Meetings, Potato Chip Institute, Internat'l. pp. 9-10. (MQ 2).

Hruschka, H. W. and E. J. Koch. 1964. A Reason for Randomization Within Controlled Environmental Chambers. Proc. Amer. Soc. Hort. Sci. Proc. 85:677-684. (MQ 2-31).

Johnston, E. F., H. V. Toko, and J. B. Wilson. 1965. Pallet Box vs. Deep Bin; a Comparison of Potato Quality. Maine Agr. Exp. Sta. Bull. 636. (MQ 2-35).

Porter, W. L. and P. H. Heinze. 1965. Changes in Composition of Potatoes in Storage. Potato Assn. of America Potato Handbook, 10:5-10. (MQ 2).

Sandar, N., A. M. Cooley and L. A. Schaper. 1964. Effects of Storage Temperatures of Red River Valley Potatoes on Flake Quality. U. S. Dept. Agr. ARS 74-30, National Potato Utilization Conf. Report 14:58-64. (MQ 2-69).

Wilson, J. B. and J. H. Hunter. 1965. Airflow Effect of Isopropyl N-(3-Chlorophenyl) Carbamate (Chloro-IPC) Applied to Bulk Bins of Potatoes. Amer. Potato Jour. 42:1-6. (MQ 2-31).

Postharvest Disease Control

G. J. Griffin. 1964. Effect of Chilling on Phenol Metabolism and Fusarium Infection of Cut Potato Tissue. Phytopathology 10:1275-1277. (MQ 2-64)

CUT FLOWERS AND ORNAMENTALS

Market Quality Research Division, ARS

Problem. The rapid increase in production of field-grown narcissus, gladiolus, lilies, stocks, and chrysanthemums into a multimillion dollar business in Florida, California, and other states has raised many problems in marketing. Methods of packaging, as related to cooling and market life, temperature requirements during transport and for limited storage periods, atmosphere modifications for storage and transit, and the control of Botrytis rot are among the most urgent research needs.

USDA PROGRAM

The Division has a limited program in market quality research on cut flowers and ornamentals, amounting to approximately 2.0 professional man-years. This research is conducted at the Fresno and Beltsville laboratories and at the Gulf Coast Experiment Station under a cooperative agreement with the Florida Agricultural Experiment Station. The California work is supported in part by the California Floral Traffic Conference and the California Florist Association.

Projects terminated during the year included: Maintenance of quality in cut flowers in ornamentals during transit, storage and marketing. (MQ 2-15)

PROGRAM OF STATE EXPERIMENT STATIONS

Market quality research on flowers and ornamentals at the State stations includes research on the storing and packaging of woody ornamentals; the storing and handling of evergreen nursery stock; and other storage studies with ornamental plant material to determine temperature tolerance of plant parts and species, to relate humidity, temperature, air movement, and type of storage wrapper or container to drying out, to determine the effect of storage atmosphere and light upon successful keeping and subsequent growth, and to develop improved storage techniques.

The relation of respiration to development, senescence, and keeping quality of flowers is under investigation. Such research is designed to establish respiration curves for flowers of certain ornamental plants during floral development and senescence; to investigate the influence of temperature on respiration rates, storage life and keeping quality of cut flowers; and to investigate the value of chelating agents and preservatives for modifying respiration and extending storage and keeping quality of flowering plants. Other factors receiving study in connection with the keeping quality of cut flowers are the pH of the holding solutions, humidity, air movement, and ethylene and carbon dioxide accumulation in storage chambers.

Grades and standards for cut flowers are being studied in connection with regional project NCM-35, Market Grades and Standards for Specified Cut Flower and Potted Plant Crops. Included for study in this project are roses, chrysanthemums, Easter lilies, poinsettias, and snapdragons.

Total market quality research effort on cut flowers and ornamentals at the State stations is approximately 9.6 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Quality maintenance in handling and packaging

1. Controlled Atmosphere Packaging for Roses. A polyethylene bag perforated with 24 pin holes and holding 100 blooms provided desirable atmospheres for roses during simulated air-transit conditions of 50° to 60° F. for 30 to 40 hours. Initial oxygen levels in the bag were lowered to 3 to 6%. Use of an unperforated bag resulted in oxygen levels of 1 to 2%, which were injurious at these temperatures. A test shipment of roses was made from San Francisco to New York and return (26 hours), using an upright carton with four compartments, each holding a bag with 100 roses. The oxygen level at the end of the trip was 5% and the quality of the blooms was excellent, with very little physical or other damage to the flowers. (MQ 2-105)
2. Narcissus. The shelf life (during 48 hours holding at 70° F.) of King Alfred daffodils was not lengthened by including 100 to 2000 ppm dimethylamino-succinamic acid (Alar), or 1 percent dimethylsulfoxide (DMSO) in the vase water (MQ 2-15)
3. Snapdragons. Adding 10 to 1000 ppm Alar to the vase water did not increase the shelf life of snapdragons during a 1-day holding period at 40° or 70° F. Packaging snapdragons in perforated polyethylene bags for 3 days markedly increased flower abscission, presumably from accumulated ethylene. (MQ 2-15)

B. Quality maintenance in storage

1. Controlled Atmosphere Storage of Roses. Low oxygen atmospheres (1/4 or 1/2%) retarded petal opening of cut roses and blueing of red varieties, but slight injury occurred in some blooms held in these atmospheres for 3 weeks at 32° F. One-half percent oxygen was the most satisfactory of the low oxygen atmospheres tested. The addition of 5% CO₂ to low oxygen atmospheres curled the tips of petals slightly and increased blueing of some varieties. (MQ 2-105)
2. Controlled Atmosphere Storage of Carnations. The storage life of carnations was extended to 4 to 5 weeks by holding the flowers in an atmosphere of 0.5% oxygen. Petal color was well preserved and spread of Botrytis decay was reduced. Adding 5% CO₂ to the above atmosphere was of no distinct benefit. A temperature of 36° F. maintained carnation flowers in better condition than 32° during 4 to 5 weeks' storage. Red carnations tended to bleach when stored at 32°.

Commercial storage of carnations in controlled atmospheres (0.5 to 1.0% oxygen) has been developed in a pilot operation in cooperation with a grower and shipper. Accumulation of 1 to 2% CO₂ caused no undesirable effects. Temperatures were maintained at about 36° F. The shipper has found CA to be a great aid to his marketing program. (MQ 2-105)

3. Controlled Atmosphere Storage of Daffodils. King Alfred daffodil flowers stored in 100% nitrogen at temperatures from 32° to 70° F., had a longer display life at 70° than those stored at comparable temperatures in air. Daffodils stored 3 weeks at 32° in nitrogen lasted 40 hours longer than those stored in air. When stored 2½ days at 70°, those in nitrogen lasted 64 hours longer than those stored in air. Storage in 99% nitrogen and 1% oxygen was somewhat less effective than 100% nitrogen. (MQ 2-105)

C. Postharvest disease control

1. Carnations. Decay of carnation blooms inoculated with Botrytis cinerea was effectively controlled with a 2,6-dichloro-4-nitroaniline (Botran) or 2-aminobutane bicarbonate spray. The latter material was also effective as a volatile when applied by a pad containing the fungicide. Botran left an unattractive residue on the flowers. Slight injury to some flowers treated with 2-aminobutane bicarbonate occurred when either method of application was used. Captan, 2-aminobutane acetate, or dibromotetrachloroethane (DBTCE) were not effective in controlling Botrytis decay of carnations. (MQ 2-105)

2. Mistletoe. Aspergillus sp. was the predominant fungus observed in packaged mistletoe in 1964-65. It was particularly severe on leaves and twigs. Inoculations of leaves and twigs were successful only after tissues had first been injured. Histological studies show fungus hyphae to be intra or intercellular. No evidence was obtained that infection of leaves occurs through stomata. (MQ 2-15)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Maintenance in Storage

Asen, Sam, C. S. Parsons, and N. W. Stuart. 1964. Controlled Atmosphere for Storing Flowers. *Florists' Exchange* 141(24):30, 45, 54; also *Southern Florist and Nurseryman* 78(16):12-13. (MQ 2-105)

INSTRUMENTATION FOR OBJECTIVE MEASUREMENT OF MARKET QUALITY

Market Quality Research Division, ARS

Problem. Agricultural commodities vary widely in many of the factors that determine market quality. A continuing need exists for more and better instruments for use in the marketing of agricultural commodities, including instruments to measure color, moisture content, texture, maturity, composition, and to detect defects in a wide range of commodities. Inspection and grading services, food handlers and processors, and research workers in the broad field of agricultural marketing could make use of instruments of this kind. The development of techniques of measurement suitable for use in automatic sorting is included in this area. The rapid conversion to mechanical handling of agricultural commodities makes it imperative that automatic devices be developed to evaluate and control the quality of the product.

USDA PROGRAM

The Department has a continuing program involving engineers and physicists engaged in the broad field of instrumentation, procedures and methods for use in basic and applied research on market quality of agricultural products. This work supplements other marketing research through superior instrumentation designed for the specific problem under study, and is cooperative with other units of the Division.

The federal scientific effort devoted to research in this area totals 4 professional man-years.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The State stations have a continuing program of research directed to developing objective measures of quality. The program deals with a number of agricultural commodities and products derived from food and fibrous crops.

While subjective judgments of quality by taste, odor, touch or appearance, using consumer panels, are too slow and costly to keep pace with modern production and marketing demands, nevertheless, they normally serve as the baseline for establishing the adequacy of objective methods. A considerable portion of the station research program dealing with objective measurements constitutes parts of studies which have other aims, such as identifying quality factors, measuring the effects of production practices on quality, or developing better methods for handling and storage of agricultural commodities.

Studies at the Massachusetts station are in progress designed for continuous on-stream color monitoring for processing of fruit juice products such as cranberry juice cocktail. Food scientists at many stations are studying objective methods of measuring texture, color, and flavor components in raw and processed products. The influence of processing treatments and storage stability on food quality is determined by a wide variety of optical and other light-measuring instruments. One investigation has been concerned with the non-destructive sampling and detection of water core defects in apples and the internal breakdown scores in such fruit. Another study subjects strawberries to a microscopic examination for cellular changes in structure related to texture and determines color quality with a Hunter color difference meter.

Other studies of vegetable quality seek to develop and standardize reliable objective methods for evaluating potato texture and apply them to research and production quality. Among the several regional marketing projects concerned with quality standards, that of the Northeastern area, NEM-30, entitled Quality Maintenance, Measurement and Control in the Marketing of Vegetables, illustrates the broad attack on this important technological area. Eight stations of the 12 in this region are conducting work to "develop objective methods for measuring quality, correlate these with market acceptance, and utilize these methods in developing grades and standards and quality control procedures." Work at one contributing station, for example, is progressing on the value of a simple punch test for rapidly determining the firmness of peas and cucumbers using an Instron universal testing machine. This speedy procedure gave excellent correlation with the much slower chemical analysis for alcohol-insoluble solids and could offer advantages for quality control of processing.

Measurements of applied force using shear presses, penetrometers, and viscosimeters have been studied for meats, cheese, jams, and jellies to determine their value in quality assessments by station investigators. New attachments to the shear press have been developed for better metering the tenderness-maturity factor of raw vegetables. Gas chromatography has been increasingly applied in many investigations seeking to measure critical chemical components of foods and other agricultural commodities. The New Jersey station has developed chemical methods, for example, to determine the concentration of new coccidiostatic drugs added to animal feeds. Fluorimetry can now replace microbiological assay methods for speedily and accurately determining certain antibiotics in feeds.

A total of about 19.3 professional man-years is devoted by the States to research on instrumentation for objective measurement of market quality.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Fruit and Vegetable Quality Measurements

(a) Apples. A contract was negotiated to develop equipment using light transmittance techniques for sorting apples for maturity and water core. The contract calls for a unit which will orient the apples, measure the light transmitted through the fruit at four wavelengths, and from this information compute an index of maturity and an index of water core. The apples are to be sorted into four categories at the net rate of three per second. It is anticipated the unit will be available for test in the harvest season of 1967.

Tests to determine the effect of position on the maturity and water core measurements indicated that, while an apple is being measured, the main axis of the apple and the optical axis of the instrument should coincide and be within 10° of each other.

Work on detecting internal browning in apples indicated that the four-filter difference meter gave improved results in detecting low levels of browning because the chlorophyll content of the fruit could be evaluated at the same time that the browning measurement is made. The results indicated that the dividing line between sound fruit and apples with internal browning changed with time as the apples ripened in storage. The main factors which appeared to be useful in predicting which apples would develop internal browning were maturity and water core. These factors can be evaluated at harvest time.

An index of scald was developed for use in evaluating low levels of scald on Red Delicious apples. This index is the ratio of two reflectance measurements, or $\frac{R \text{ 730 nm}}{R \text{ 800 nm}}$. A similar index of color was de-

veloped for Red Delicious apples; i.e., $\frac{R \text{ 620 nm}}{R \text{ 670 nm}}$.

Preliminary exploration of the use of sonic energy to indicate quality characteristics of apples has shown promise. Equipment has been obtained for inducing sonic vibrations in apples and measuring the magnitude of these vibrations as a function of frequency. The frequency range from 20 to 2000 cps is scanned and the amplitude of vibrations recorded as a continuous curve. Obvious differences in the recorded curves were obtained for hard and soft apples, but reproducible measurements were difficult. Improved methods of coupling the sonic energy to the sample must be developed before a useful analysis can be made. A research contract has been negotiated with an industrial firm to develop techniques for making sonic measurements. This contract should provide the needed background information.

(b) Blueberries. A test was carried out to correlate light transmittance measurements with the concentration of extracted anthocyanin pigment. Analysis of the data has not been completed at the close of this reporting period.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Objective Measurement and Evaluation of Quality.

Birth, Gerald S., and Olsen, Kenneth L. 1964. Nondestructive detection of water core in Delicious apples. Proc. Am. Soc. for Hort. Sci. 85: 74-84.

Yeatman, John N. and Norris, Karl H. 1965. Evaluating internal quality of apples with new automatic fruit sorter. Food Tech. 19(3): 123-125.

MARKETING FACILITIES, EQUIPMENT AND METHODS

Transportation and Facilities Research Division, ARS

Problem. Returns to producers and prices paid by consumers for horticultural crops are adversely affected by the use of inefficient marketing facilities, equipment, and methods. Better work methods, techniques, devices, operating procedures, equipment, and facility designs are needed for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, and other horticultural crops. Such improvements at shipping points would increase the productivity of labor, prolong the storage life of the commodities, reduce bruises and injuries to these products, reduce marketing cost, expand consumption, and reflect greater returns to producers.

USDA PROGRAM

This is a continuing long-range research program covering the development of improved work methods, techniques, devices, operating procedures, equipment, and facility designs for precooling, conditioning, storing, handling, cleaning, washing, waxing, sorting, sizing and packing potatoes, citrus fruits, deciduous fruits, vegetables, and other horticultural crops. Potato research is carried on at the Red River Valley Potato Research Center, East Grand Forks, Minn.; the Potato Handling Research Center, Presque Isle, Me.; a field office at Gainesville, Fla., and the Hyattsville, Md., office; in both laboratory and commercially owned facilities; in cooperation with the North Dakota, Minnesota, Maine, and Florida Agricultural Experiment Stations, the Red River Valley Potato Growers' Association, the Market Quality Research Division, the Agricultural Engineering Research Division, the Marketing Economics Division of ERS, and the Forest Products Laboratory of the Forest Service. Citrus fruit research is carried on by field offices at Gainesville, Fla., and Athens, Ga., in cooperation with the Florida Agricultural Experiment Station, the Agricultural Engineering Research Division, the Market Quality Research Division, and commercial packers. Deciduous fruit research is carried on by the Wenatchee, Wash., and Athens, Ga., field offices and by the Hyattsville office; in both laboratory and commercially owned facilities; in cooperation with the Washington and Georgia Agricultural Experiment Stations, and the Market Quality Research Division. In Michigan research on deciduous fruits is conducted under a cooperative agreement and a research contract with the Michigan Station. Vegetable research is conducted by the Gainesville, Fla., and Athens, Ga., field offices, in commercial packing plants and in laboratory facilities of the University of Florida, in cooperation with the Florida and Georgia Agricultural Experiment Stations and with the Market Quality Research Division. Sweetpotato work in North Carolina is conducted under a cooperative agreement with the North Carolina Station.

The Federal effort devoted to research in this area during the fiscal year 1965 totaled 12.4 professional man-years (0.3 extramural); 4.7 to potatoes; 2.3 to citrus fruits; 3.2 to deciduous fruits (0.1 extramural); 0.9 to vegetables (0.2 extramural); and 1.0 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Handling, Degreening, and Packing Citrus Fruit

This research, at Gainesville, Fla., is directed toward developing improved methods, devices, equipment, and facilities for conditioning, handling, and packing citrus fruits at Florida shipping points.

For the first time in this research on degreening, fruit color was measured by instrument as well as by human judgment used with reference color plaques. The ratiospect, an instrument developed by the Department of Agriculture, was used for fruit color measurements on a laboratory scale. This instrument functions by means of light transmission through a single fruit at a time and measures chlorophyll sensed by the beam of light passing through the fruit.

Grove-run fruit was visually sorted into three color classes; dark, medium and light green, providing suitable quantities for the procedure to be followed. Each fruit was given an initial color rating by both the ratiospect and the reference plaque method. Weight, height, and diameter were also obtained. Samples of fruit were then put in mesh bags and placed in a room for degreening under standard conditions. At 12-hour intervals the samples were removed at random and given a color rating by use of both the ratiospect and color plaques (each fruit rated for color). This procedure was followed for a period of 84 hours and at the end, final color readings were made. Also the fruit was again weighed and the height and diameter measured.

Results from ratiospect color ratings agreed essentially with previous work and indicated that there is a time difference of from 12 to 24 hours for degreening between light green and medium green fruit.

Color measurements by both the ratiospect instrument and by reference color plaques showed that fruit passed the acceptable color in approximately the same length of time in the degreening room. In the color measurements by the ratiospect instrument, there was a noticeable influence from the size of the fruit; a longer time was required to reach acceptable color as the size of the fruit decreased. The ratiospect detected approximately a 50 percent change in chlorophyll during the first 24 hours of degreening, 30 percent during the next 24 hours, and only 20 percent change in the third 24 hours. By the plaque measurement, change in chlorophyll was rated about 20 percent during the first 24 hours, 40 percent during the next 24 hours, and 40 percent during the third 24 hours.

These tests also indicated fruit could be satisfactorily sized before degreening, as shrinkage in fruit diameter was found to be approximately 1/32 of an inch with a weight loss of 3 percent during an 84-hour degreening period.

Handling data obtained during the 1963-64 season on complete commercial-scale pallet box systems were summarized and related to other data and information already accumulated. An outline for a manuscript was prepared and the basis for the principal comparative relationships which might be included in the report were evaluated. Time values were developed for various cycles of operations in the full-bulk system of handling citrus so as to make it possible to relate computed manpower needs to actual manpower use in given situations in the sequence of operations from the picker to the packinghouse. Work on process charts was extended and about 200 feet of 16 mm. color movies were made of fruit handling systems needed to supplement the movies previously obtained on citrus handling. Further editing was done on the movie as a whole.

Data were obtained on the sizing of grapefruit by a transverse, expanding-roll sizer which is a different type of equipment to that regularly used in Florida for sizing fresh citrus fruit. These data showed that the standard deviation of the equatorial fruit diameter measurements and the coefficient of variation of these measurements were reasonably close to those found in earlier studies on sizing grapefruit by conventional belt-and-roll sizers, and indicates comparable performance. These results were incorporated with data which have been accumulated over a period of several years. They also were made available to the management personnel of the packinghouse where the study was made who expressed misgivings relative to the capability of the transverse, expanding-roll sizer to size grapefruit satisfactorily and in a way comparable to the belt-and-roll type of equipment. However, from these observations it appears that the transverse, expanding-roll sizer does have sufficient flexibility for sizing all types of citrus fruits.

B. Handling and Packing Deciduous Fruits

This research is directed toward the development of more efficient work methods and equipment for handling, washing, sorting, sizing and packing apples. It includes a study of the impact of electronic color sorting of apples on related packinghouse operations and an evaluation of presizing and presorting apples in commercial storages and packinghouses.

1. At Wenatchee, Wash., a substantial amount of time was devoted to further development work on an improved packing line designed around a unitized brush-sizer. During the construction of the line numerous problems and technical questions arose that had to be solved and answered. Testing was continued on the brusher mock-up to arrive at the optimum rotational rates for both the brushing and sizing operations. A Memorandum of Understanding was negotiated with a commercial apple packing firm at Monitor, Wash., for

the installation and testing of the line under commercial operating conditions. Layouts incorporating the brush-sizer, distributor belts, and return-flow belts for both fancy and extra fancy grade apples, were prepared for the facility.

A pallet box filler which lowers apples into the box between successive pairs of padded rollers was designed. This filler should distribute apples more evenly within the pallet box than present fillers and place them more gently in their position of rest. A prototype is under construction in the shop of the Agricultural Engineering Research Division, whose research personnel see application of the new filler in harvesting and orchard handling operations.

Effort was concentrated on obtaining a second year's data on the operation of the electronic color sorter to determine its effect on other packinghouse operations. Additional recordings were made to fill out and complete data previously taken on the rate of input, proportion of unfilled cups, and the number of apples knocked off in the singulating process. Interviews and discussions were held with management and operating personnel of the plants having electronic color sorters to obtain their impressions, opinions, and reactions to this new color sorting method, and to obtain cost figures relating to the operation.

Data obtained tend to confirm that: (1) The high cost of the equipment makes its use feasible only in the largest packinghouses; (2) the additional handling involved subjects the fruit to further bruising; (3) the capacity of the equipment is limited by the necessity of feeding apples single-file through the scanners, 10 to 30 percent of the cups go through the scanners unfilled; (4) a higher volume of extra fancy fruit is delivered to the packers; (5) the fruit is color sorted to a high degree of accuracy (for both red and golden apples); and (6) maintenance is highly specialized.

2. At East Lansing, Mich., further work was done on editing the Michigan Station's final report under a cooperative agreement covering the design of equipment which uses water as a medium for dumping, sorting, sizing, and filling apples back into pallet boxes. This report will be published under the title, "Development of a Hydro-Handling System for Sorting and Sizing Apples for Storage in Bulk Boxes," during the second half of 1965.

During the report period, a research contract for designing, constructing, and testing a prototype hydrohandling system for the prestorage sorting and sizing of apples was developed and negotiated with Michigan State University effective June 2. Initial work involves design drawings of the system and its component parts.

3. At Athens, Ga., a study to develop guidelines for preparing improved layouts for commercial peach packinghouses was 75 percent completed. Data on facilities, equipment, work methods, and operating procedures were obtained in commercial peach packinghouses in Georgia and South Carolina.

It was found that because of the amount of variability that exists between peach packinghouses, it would be difficult to develop one or two layouts that would be applicable to the entire industry. It was necessary to synthesize three peach packing operations and to develop plant layouts for these in such a way that they would have the widest possible range of applicability. Three layouts were developed; they can be used in open-type sheds or facilities of conventional construction and can be scaled up or down in size depending upon the needs of the packer. These layouts should provide the industry with useful guidelines for developing or modifying peach packinghouses to improve operating efficiency and reduce costs.

An evaluation of the most widely used methods of receiving and dumping peaches was initiated during the 1964 season. Data were obtained on three methods of receiving as follows: (1) Conveyor; (2) two-wheel clamp truck; and (3) pallet and forklift truck. The two methods of dumping evaluated were: (1) Manual and (2) automatic.

Studies of receiving and dumping were continued during the 1965 packing season with emphasis on the pallet-box method, which is an innovation in handling peaches. Labor and equipment inputs were determined by stop watch time study, micromotion study, production studies, and other industrial engineering techniques.

4. In the Hyattsville, Md., office work was continued on a manuscript "Apple Packing Methods and Equipment." Personnel at the Wenatchee, Wash., field office have reviewed the first part of the manuscript. This report will contain a description and analysis of methods and equipment for preparing apples for the fresh market, excluding sorting.

C. Handling and Packing Potatoes

1. Presque Isle, Me. Research under this project is directed toward reducing operating costs of potato storages and packinghouses by increasing the productivity of labor employed and reducing losses from bruises and mechanical injuries in handling, storing, cleaning, grading, sizing and packing potatoes. It involves the development of more efficient work methods, operating procedures, equipment, and facilities for handling, storing, and preparing for market Maine potatoes.

Work was completed on the manuscript, which is scheduled for early release during fiscal year 1966, as ARS 52-8, "Bulk Handling and Quality Evaluation of Potatoes Shipped in Conveyorized Railroad Cars." Work also was continued on a manuscript, "Supplying the Packing Line with Potatoes in Maine Storages at Rates of 200 Hundredweight Per Hour and Above." An article, "An Evaluation of Hopper-Type and Dump-Type Truck Bodies for Potatoes," was prepared and cleared for publication in the Maine Farm Research Quarterly.

Experiments on bruise resistance of potatoes as related to changes in temperatures of the surrounding air were continued. The test apparatus for measuring bruise resistance was modified to permit use of a different technique for increased accuracy. Test data showed that potatoes 24 to 28 weeks after harvest had a greater resistance to bruising; reversing the trend of decreasing resistance occurring during the first 20 weeks of testing.

Time studies were made of bagging operations and of potato handling with a scoop mounted on an industrial lift truck.

2. Gainesville, Fla. This research has as its objective the development of more efficient work methods, operating procedures, and equipment for the handling and preparation for market of potatoes in spring crop areas.

A manuscript entitled "Systems for Bulk-Handling Spring Crop Potatoes from Harvester to Packing Line" was prepared. The bulk-dumping system, which was developed and tested, had a total cost of approximately \$18 less per one thousand packed hundredweights of potatoes than for a pallet box system of handling. Also the bulk-dumping system cost about \$14 less per one thousand packed hundredweights than the conventional hopper-body sloping-bottom bin system. Another advantage of the bulk-dumping system is that multiple use of trucks and bin facilities are possible. Trucks, which are basically flatbed, can be used for other purposes during off seasons. In addition, the design of the potato bin permits storage of equipment and other items during off seasons.

During this report period, mechanical bag-sewing equipment was installed at a potato packinghouse to test a replacement for hand stitching. In this installation one-hundred pound burlap bags of potatoes were closed by a sewing machine mounted on a column above a belt conveyor. The sewing head, of the type commonly used to close paper bags, made four double-locked stitches per inch and successfully closed the bags during the tests. Time studies showed that by hand sewing bags one worker could close approximately 285 bags per hour, but that 667 bags per hour could be closed by one operator and a machine. In addition to reducing the number of manual bag sewers, machine sewing should make possible a reduction in the number of workers assigned to transfer filled bags from the packing stations to the take-away belt, (4 to 5 workers might be eliminated from the packing crew in most Florida potato packinghouses).

Because of labor problems in the cooperator's packinghouse, a complete evaluation of this system was not possible. However, observations made to improve future tests on a machine bag-sewing system include the use of a two- to three-inch longer burlap bag; use a machine which sews with a single thread rather than a double thread; and use an elongated input guide to the sewing head.

Before adopting this bag sewing method, a packinghouse operator should consider the problem of equipment breakdown, which includes breaking needles and thread, incompletely closing bags, and other machine failures. The importance of this problem cannot be overemphasized in that a very short breakdown of the sewing machine will cause the entire packinghouse to shut down while repairs are made.

3. Red River Valley Potato Research Center, East Grand Forks, Minn. Work is directed toward developing more efficient work methods, techniques, devices, and equipment for the handling and preparation for market of mid-western fall-crop potatoes.

Visits to a number of commercial plants, doing both "wet" and "dry" grading, to observe packingline operations indicate that inaccurate sizing and grading are a major problem. General inefficiency of methods and equipment also was noted. Plant and storage layout was also a key factor in handling and packing.

At the dry-grading plants, a significant trend toward the use of small powered scoops for moving potatoes from storage to the packing line was evident. Although bulk shipments in rail cars appear to be on the increase, there is a lack of equipment for bulk loading railroad cars. These findings pointed up the possibility of a future shift to permanent dry-grading lines rather than the present small portable ones. Presently, there is a shift to "full bulk" handling from the storage to the transporting vehicle which is adaptable to both seed and process stock.

Previous work on "Moving Potatoes From the Storage to the Packing Line" was thoroughly reviewed with emphasis on identifying partially completed work that should be finished. A plan was evolved for updating, analyzing, and completing a set of partially completed data for publication.

Pontiac potatoes were again sized into storage directly from bulk trucks using a portable, expanding pitch, spool sizer at a rate of approximately 10 cwt. per minute. The sizer was set to divide the potatoes into the following diameter categories: less than 2 inches, 2 to 3½ inches, and greater than 3½ inches. A "deformed" canvas belt feeding mechanism was used to transfer the potatoes from a 2-foot-wide conveyor onto the 4-foot-wide sizer. During the sizing operation, both damage samples and field-run samples were collected and a standardized lot was periodically run through the sizer to check sizing accuracy.

The sizer damaged about 50 percent of the potatoes, with the potatoes larger than 3½ inches receiving the most damage. This damage was all non-grade defects. By count, 5 percent of the field-run potatoes fell in the less than 2-inch size, and 5 percent in the greater than 3½-inch size category. Ninety percent were in the 2 to 3½ inch category. The sizer being used was not accurate enough to further refine this distribution. Part of the sizing accuracy problem is to get a uniform feeding of tubers onto the sizing spools and then to provide a consistent orientation as the tuber moves across the spools. These results are consistent with those found the preceding year.

Twenty-four 50-pound capacity sample bags were placed in the storage. The total contents of the bags, and also 20 selected tubers from each bag, were weighed before and after storage to evaluate weight loss. Each of the 20 selected tubers also were accurately measured to evaluate size change during storage. After storage at approximately 40° F. for seven months, the average weight loss, which includes losses from respiration and rot, was 5 percent; within a range of from 4 to 6½ percent. The following decreases in original dimensions were found: length, 2 percent; width, 2½ percent; thickness, 2½ percent.

A 120 cwt. bulk truckload of potatoes was hand sized in order to obtain the sample distribution of 50-pound samples. The results will make possible more precise sampling for estimating field-run size distributions.

An experiment was conducted to measure specific weight (pounds per cubic foot) and the percent void space for the three size categories of potatoes used in the sizing work. The results were as follows: Potatoes of less than 2 inches, 42.2 lbs. per cubic foot and 37.1 percent voids; 2 to 3½ inches, 41.5 lbs. per cubic foot and 38.7 percent voids; greater than 3½ inches, 39.6 lbs. per cubic foot and 40.7 percent voids. The specific gravity of these potatoes was 1.07 percent. If the specific gravity had ranged from 1.05 to 1.09, the greatest specific weight difference would be 4.1 lbs. per cubic foot. This range, which is the extreme, is about 10 percent of the normal specific weight, and would not be considered important in structural design since other factors vary more than this.

D. Handling and Packing Vegetables

At Gainesville, Fla., this research has as its objective the development of improved work methods, equipment, devices and operational procedures for the handling and preparation for market of vegetables at shipping points.

Work was completed on Marketing Research Report No. 691, "Reducing Costs of Packing Mature-Green Tomatoes at Florida Shipping Points," which was released in May 1965.

Previous work has established that manual packers on mule trains do not accurately size celery. This season a test was made to size celery stalks by weight. Celery was separated by weight into sizes and packed in wire-bound crates. Average stalk weights were: 2.338 lb., 1.877 lb., and 1.553 lb., respectively, for sizes 2, 2-1/2, and 3. Size 2-1/2 and size 3 averaged very close to the desired average weight of 1.89 and 1.56 lb., respectively. However, size 2 stalks had an average weight slightly heavier than the desired weight of 2.25 lb. This was caused by including size 1-1/2 stalks in the size 2 crate. In actual practice, size 1-1/2 stalks, although few in number, should be separated and packed as a separate size.

More consistent weights of packed crates is another benefit from weigh-sizing celery. The average crate weight for size 2 celery was 61.62 lb.; size 2-1/2 was 61.82 lb.; and size 3 was 61.41 lb. The range between the heaviest and lightest crate weight was 5.08 lb. for size 2; 3.120 lb. for size 2-1/2; and 3.106 for size 3. For comparison, the range between the heaviest and lightest weight for crates that were packed by workers on mule trains was: 7.316 lb. for size 2, 7.794 lb. for size 2-1/2 and 8.308 lb. for size 3.

The low ranges between heaviest and lightest crate weights in the weigh-sizing and packing tests signifies that workers should have no problem with slack packs or too full crates when packing weigh-sized celery in crates.

Under a trust-fund cooperative agreement with a private firm (a Florida celery grower and packer) funds were made available for the development of weigh-type celery sizing equipment. With these funds, a small-package, highly accurate, continuous motion weigher was purchased for further tests. In simulated tests this type of machine weighed 200-225 celery stalks per minute with a \pm 0.01-0.015 lb. accuracy or expected weighing error between weight zones. A series of conveyors to orient, accumulate and feed stalks onto the weigher also were obtained with trust funds.

E. Storage of Deciduous Fruit

1. Room Cooling Rates. The purposes of this research, at Wenatchee, Wash., are to: (1) Measure and evaluate the cooling rates of fruits in storage and shipping containers in terms of container designs that properly protect the fruit, shorten the cooling period, and maintain the fruit at proper storage temperatures; and (2) develop improved handling, stacking, and storage practices.

Cooling rate studies were run on packed boxes of apples. The fiberboard boxes used in the tests had been previously compression tested and special large holes placed in the ends of the boxes. There was an appreciable difference in the cooling rate of fruit in box No. 1, which did not have any holes in it, and box No. 6, which had the following holes in each end: one oblong slot $1\frac{1}{2}$ inches down from the top of the box 4 inches long by one inch wide with rounded ends and centrally located; and three additional holes 2 inches in diameter, in each end, one located centrally in the end and one in each lower corner $3\frac{1}{2}$ inches in from the sides and $1\frac{1}{2}$ inches up from the bottom. After cooling 17 hours box No. 6 had cooled to a temperature 10° F. lower than box No. 1.

A cooling study was made to compare the cooling rate of packed peaches in uncovered stacks on pallets and packed peaches stacked on pallets and covered with polyethylene to retain the moisture. The starting temperature was $80-85^{\circ}$ F. Stacks of peaches covered with polyethylene cooled to a temperature of 40° F. in 4 days. The check stack of peaches (without covers) cooled to 41° F. in approximately 36 hours. At the end of 24 hours

the temperature of the peaches under the polyethylene covers were 20° F. higher than the peaches without covers. This test indicated that packed boxes of peaches on pallets to be held in a cold storage, should be pre-cooled before covering with the polyethylene.

2. Refrigerated Storage. The objectives of this project at Wenatchee, Wash., are to: (1) Investigate airflow and distribution methods, patterns, and rates in refrigerated fruit storages to determine and evaluate the influence of these factors on cooling fruit and on bringing it to optimum storage temperatures; (2) determine and evaluate heat gains through various structural features of fruit storages and make suggestions for improved designs; (3) redesign storage houses for the most efficient handling and storage of fruit in pallet boxes; and (4) evaluate hydrocooling of apples before they are placed in storage.

Tests on air temperatures and air distribution have indicated the necessity of knowing the temperatures at all points in a cold storage room filled with apples. Because of these findings many operators of cold storage houses are now placing thermocouples throughout their storage rooms as an aid in better temperature control. This has helped in giving the apples a longer storage life and better quality fruit.

Preliminary steps have been taken to prepare material for a report on cold storage operations for apples. It is now intended that this report will cover the following subjects: (1) Refrigeration equipment and its operating characteristics; (2) cooling capacity; (3) relationship of cooling rate to humidity control; (4) air volume and air circulation; (5) need for rapid cooling--removal of field heat; (6) fruit temperature in relation to storage life; (7) humidity control and atmospheric conditions that effect apple quality in storage; and (8) rates of cooling as effected by containers and stacking methods.

3. Controlled Atmosphere Storage of Apples. Work on this project is designed to develop improved methods, techniques, equipment, and facilities for the controlled atmosphere (C.A.) storage of apples in the Pacific Northwest, and is in cooperation with the Market Quality Research Division.

Observations were continued on the commercial storage of apples in controlled atmosphere. The types of C.A. storages included are: (1) Regular C.A. which uses caustic soda as a scrubbing material to remove carbon dioxide (CO_2) from the room atmosphere. With this system the room must be airtight, first cost of construction is high, and requires close attention for operation; (2) Tectrol C.A. which delivers correct atmosphere to the room. It is expensive equipment (on rental basis only), rooms do not have to be sealed airtight (one air change in two days is allowed), and quick pulldown to desired atmospheric conditions which permits opening the room at any time to take out samples; (3) desomatic absorber or molecular sieve which uses a burner to remove oxygen from the air. This unit can be purchased. The molecular sieve removes all impurities from the room air, requires the

installation of a humidifier to maintain proper relative humidity in the room, and also is capable of quick pulldown; (4) water scrubber used to remove CO₂ from room atmosphere. This system must have an airtight room and has a high first cost. It is not recommended for rooms where the temperature is low or the CO₂ content of the room has to be less than 2½ to 3 percent; and (5) lime scrubber, uses slack lime as a scrubber to remove the CO₂ from the atmosphere. Lime can be left in the bags, requires airtight rooms, disposal of used lime could give some problem unless there is need for it in the area.

F. Storage of Potatoes

Work under this program, at the Red River Valley Potato Research Center, is directed toward providing optimum storage conditions for fall-crop potatoes for table stock, seed, and processing; and developing improved layouts and designs for potato storage houses, which will permit the use of the most efficient handling and packing methods, keep injuries and mechanical damage to a minimum, and minimize construction and maintenance costs.

1. For Table Stock and Seed. Plans and specifications were completed and distributed for a 60,000 cwt. door-per-bin potato storage. These are identified as Potato Storage, Plan No. 5979, through the Cooperative Farm Building Plan Exchange. Sixty-two sets of reproducables have been distributed throughout the United States. The plans consist of twelve sheets of design drawings and sixteen sections of specifications.

The storage is divided into six bins, each having a storage capacity of 10,000 cwt., and a shipping room having a packing and shipping capacity of about 1,000 cwt. per day. In general, the suggested construction is single-story wood frame containing approximately 16,000 square feet in overall area. The storage is designed mainly for table stock in the fall-crop areas.

Designing, drafting, and specification writing were about 75 percent completed on a 20,000 cwt. capacity arch roof potato storage, intended primarily for seed and processing stock. It is expected that this set of plans will consist of 8 sheets.

Designing and testing of a 20-foot span, T-section, bin front was completed. The T-section is made using 2 x 4's, 2 x 6's, or 2 x 8's as webs which are nailed and glued to a 2 x 12 flange 20 feet long. The potato pile depth determines the selection of the web thickness. This type of bin front having a 2- by 8-inch web performed very satisfactorily when loaded under a uniformly distributed test load of 80 lbs. per sq. ft. This front also performed very well under actual storage conditions for bulkheading a 20-foot span.

Preliminary designing and testing was started on a slotted bin front; a removable post front; and a circular, galvanized sheet, steel bin front.

2. For Processing. Theoretical heat balances were calculated and assistance provided; in cooperation with the University of Minnesota Agricultural Engineering Department and the Agricultural Engineering Research Division on the design, installation, and testing of refrigeration units for controlled temperature rooms in the new Processing Laboratory at the Center. A new conditioning room also was designed and constructed at the Center for use in the controlled temperature storage work of potatoes for flakes.

Controlled temperature "flake" storage work was continued under cooperative projects with Market Quality Research Division and Eastern Utilization Research Division. The general results indicate 50° F. storage temperature gives better flakes more consistently than 40° and 45° F. Another phase of this work was the continued collection of rate of weight loss and vapor pressure difference data. This year's data has much more variation than last year's and the trends are not as apparent.

A 4½-month preliminary test on the effect of high air flow rates was conducted. Tubers were exposed to 40° F., 90 percent relative humidity, and air moving at a 200 f.p.m. surface velocity. Five f.p.m. is the normal recommended velocity. Weight and dimensional changes of the potatoes were no greater than with normal air flow rates.

The comparison of shell and a combination of shell and through ventilation for 55° F. chip storage was continued. During the 1963-64 season, based on a 6-month storage period, there was about 1½ percent more shrink in initial dimensions and about 1½ percent more increase in weight loss for the combination system than for the shell system. These tests were conducted with 50-pound capacity sample bags. During the 1964-65 season, based on 4-month storage period, 87 percent of the potatoes placed in the bulk bins graded out as commercial grade chipping potatoes. The 13 percent loss was composed of the following components: weight loss 7 percent, culls 5 percent and dirt 1 percent.

G. Cooling Deciduous Fruits

This research is designed to develop improved methods, equipment, operating practices, and techniques for use in existing or new facilities for more efficient cooling of deciduous fruits.

At Wenatchee, Wash., the purpose of this project is to determine the possible advantages of hydrocooling apples prior to storage. To accomplish this, three varieties of apples were used: Golden Delicious, Starking Delicious, and Winesaps.

Samples consisting of two standard wood boxes of apples were hydrocooled to a core temperature of 40° F. by immersing the boxes in a tank of water and crushed ice. Other lots were hydrocooled to a temperature of 40° F. at 1/2 inch below the skin surface. The temperatures were determined by inserting thermocouples in the center apple of the box and temperature readings taken

with a potentiometer. When the thermocouples indicated a temperature of 40° F. the boxes were removed from the ice bath and placed immediately into storage at 30° to 31° F. and a relative humidity of 87 percent. The Golden Delicious apples were packed in fiberboard boxes having polystyrene trays and polyethelene liners before they were placed in the cold storage room.

Other boxes of apples of each variety were cooled as follows: (1) To a core temperature of 35° F. in 3 days, then placed in the cold storage (30°-31°) room; (2) to a core temperature of 35° F. in 7 days then placed in the cold storage room; (3) to a core temperature of 35° F. in 14 days then placed in the cold storage room; and (4) to a core temperature of 35° F. in 28 days then placed in the cold storage room.

Temperature records were kept and the apples sampled periodically during the storage season, pressure tested, and rated by a taste panel. The tests indicate that Delicious apples cooled in 28 days had a storage life of about 40 days, while those cooled in 14 days could be held for longer periods but had a poor quality when compared with the faster cooled apples. Apples cooled in 7 days, in 3 days, hydrocooled to a core temperature of 40° F., and hydrocooled to a temperature of 40° F. 1/2 inch under the skin had about the same storage life and quality. The one exception was Winesaps where all samples attained about the same rating during the storage season. The dessert quality (as determined by the taste panel) improved at the end of the storage season. Starking Delicious apples that were hydro-cooled had some internal core rot which other samples did not have, which indicates that water may have entered the open calyx during hydrocooling.

Under ideal cooling conditions in commercial cold storages, it would be difficult to detect any benefit from hydrocooling. In very good commercial storage houses the core temperature of apples can be lowered to approximately 35° F. in 72 hours. The tests indicate that this would be a satisfactory cooling time to help keep the apples in their best condition. However, as many storages do not have sufficient refrigeration capacity, such rapid cooling is not always obtained. This is especially true in years where there is an extra large crop of fruit. Some storage houses have taken several weeks (3 to 6 weeks) to room cool the apples to a core temperature of 35° F. or lower. In cases like this, hydrocooling would be a profitable procedure.

At Athens, Ga., the thermal conductivity of the flesh of Georgia Mountain Red Delicious apple was measured in relation to moisture content and density. An average thermal conductivity of 2.34 btu/hr. °F. sq. ft. per inch for an average moisture content of 84.9 percent was found. In tests on fruit from the same lot, to determine the temperature response by forced-air cooling, 2-3/4-inch diameter apples were cooled from 85° F. to a core temperature of 45° F. in 50 minutes. A mass-average temperature of 45° F. was reached in approximately 35 minutes. These tests were carried out on 10-bushel lots with air at an average temperature of 21.2° F. flowing at the rate of 250 feet per minute.

Construction of an experimental, mobile forced-air precooler was completed and delivered. During an extended "shakedown" period of operation, faulty design and construction features were corrected. Performance tests to determine cooling effectiveness in relation to operating costs were conducted on peaches. Preliminary results indicate commercial feasibility but no cost advantage as compared with hydrocooling.

H. Cooling Citrus Fruits

Thermal properties of Marsh grapefruit were investigated at Orlando, Fla., and at Athens, Ga. Tests were conducted on test specimens of early-, mid-, and late-season Marsh grapefruit to measure the thermal conductivity of the rind and juice vesicles and the thermal diffusivity of the whole specimen in relation to moisture content, density, and seasonal variations. These tests were completed, preliminary analyses made, and the data summarized and listed on data sheets for computer analysis. Analysis will yield temperature response equations and correlations.

Analysis of precooling data previously obtained at Gainesville, Fla., with the pilot-scale forced-air precooler chamber was completed and the manuscript "Forced-Air Precooling of Florida Citrus Fruits," was prepared for publication as a technical bulletin. Some of the significant findings include: (1) Forced-air precooling of citrus fruits in bulk containers is rapid, apparently reasonable in cost, and safe. Oranges, tangerines, or tangelos can be precooled from initial temperatures of 70° to 90° F. down to temperatures ranging from 35° to 50° F., measured as the mass-average, in an hour or less. Grapefruit will precool somewhat more slowly than oranges. Rate of precooling is dependent upon fruit size and structure. Estimated cost of providing air movement and cooling will amount to about \$0.20 to \$0.25 per hour for 1,000 lb. of fruit; (2) exposure of citrus fruits to air temperatures of 15° F. or below did not result in rind injury or increased decay. Control must be exercised so that fruit surface temperature does not fall below 25° to 28° F. Loss of weight in fruit, averaged less than 1 percent per precooling test run; (3) an airflow rate of 3,500 cfm with a static pressure of about one inch of water across the fan gave good results under the conditions of this investigation (500 and 1,000 lb. loads); (4) the largest practicable load should be precooled in a batch-type system, since cooling efficiency increases and power cost decreases rapidly with larger loads; (5) a system in which air is moved vertically, either up or down, through the load offers maximum efficiency. A container, such as a pallet box, with closed sides and slatted bottom, perhaps with additional holes in the bottom, would be satisfactory from the standpoint of cooling rate and minimum injury to fruit; and (6) forced-air precooling of citrus fruits packed in wirebound boxes, ventilated fiberboard cartons, or polyethylene bags will take place at about half the rate for the same fruit in bulk containers. Fruit packed in either non-ventilated fiberboard cartons or polyethylene bags in bagmaster cartons will precool very slowly.

I. Cooling Vegetables

This research at Gainesville, Fla., is designed to develop improved methods, operating practices, and techniques for use in existing and new facilities for more efficient cooling of vegetables.

A manuscript was prepared covering the research on hydrocooling stacked crates of celery and sweet corn. It describes hydrocooling unit loads of stacked crates of celery and sweet corn with overhead spray nozzles in a pilot plant and laboratory tests. As compared with the conventional system of hydrocooling, cooling celery and sweet corn in unit loads offers advantages of: Reduced labor costs, reduced crate rehandling, reduced crate breakage, and better quality maintenance.

In pilot-plant tests, celery crates stacked in four layers were cooled with 38° F. water from 75° down to 47.2° F. in 35.4 minutes when 63.2 gallons per minute of water was sprayed onto the stack by full-cone spray nozzles. This time compares favorably with the 29.6 minutes required to cool celery in present types of single-layer flood-type hydrocoolers.

Crates of corn stacked in five layers cooled very slowly at three waterflow rates (35.5, 63.2, and 91.2 gpm). When corn was cooled in unit load stacks from a starting temperature of 90° F., to a final temperature of 44-1/2°, a precooling time in excess of three hours was required.

J. Handling Vegetables in Pallet Boxes

1. Tomatoes. Recent developments in the production and harvesting of tomatoes, such as mechanical harvesting for processing, has brought about an urgent need for the development of larger containers than field boxes for handling this commodity. Because of this need, research on handling and ripening tomatoes in pallet boxes was undertaken at East Lansing, Mich., under a cooperative agreement with the Michigan Agricultural Experiment Station.

Research on this project was confined to reviewing, editing, and revising the manuscript, "The Handling of Mature Green and Ripe Tomatoes in Bulk Boxes," based on the final report.

2. Sweetpotatoes. This research is designed to increase the efficiency and reduce the unit cost of handling, curing, storing, and preparation for market of sweetpotatoes and to minimize losses from spoilage and deterioration. This work is being conducted at Raleigh, N. C., under a cooperative agreement with the North Carolina Agricultural Experiment Station and the North Carolina State Department of Agriculture.

The report ARS 52-2, "Pallet Boxes and Palletized Containers for Handling and Storing Sweetpotatoes," which covered the first two year's research in this area was released February 1965. A paper, "Certain Physical Properties of Sweet Potatoes" (ASAE Paper No. 64-814) was prepared and presented at the Winter meeting of the American Society of Agricultural Engineers, New Orleans, La., December 8-11, 1964.

Handling and curing tests were continued with two types of pallet boxes and palletized crates.

Respiratory studies were made of freshly dug sweetpotatoes using a Lira infrared gas analyzer and six chambers. The factors evaluated for their effects upon carbon dioxide production in the test runs included bruising and skinning damage, variety, curing temperature, and size effects. Tests indicated a respiration peak at about 10 hours after harvest when root temperature increases. The effects of damage upon respiration showed up as a greatly increased carbon dioxide evolution within a half hour of the time of damage.

Time was devoted to completing an analysis of sweetpotato handling systems. A final project report, which will be prepared based on this analysis, will include recommendations on pallet boxes and other containers for handling as well as related structural features of curing and storage houses.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE PROGRAMS

Handling and Packing Deciduous Fruits

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Matthews, R. W., Stout, B. A., Dewey, D. H., and Bakker-Arkema, F. W. 1965. Hydrohandling Apple Fruits. Paper No. 65-130, Annual Meeting of American Society of Agricultural Engineers, University of Georgia, Athens, Georgia, June 20-23, 1965.

Handling and Packing Potatoes

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Handling and Packing Vegetables

Grizzell, William G. 1965. Reducing Costs for Packing Mature-Green Tomatoes at Florida Shipping Points. Marketing Research Report No. 691, May 1965, 36 pp.

Storage of Potatoes

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Yaeger, E. C., Bouland, H. D., and Tulloss, C. S. 1965. Design and Specifications for 60,000 cwt. Door-Per-Bin Potato Storage. Federal Cooperative Extension Plan No. 5979, May 1965, Plans 12 plates, specifications 14 pp.

Cooling Deciduous Fruits

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CONSUMER PACKAGES AND SHIPPING CONTAINERS

Transportation and Facilities Research Division, ARS

Problem. It costs about 8 billion dollars a year to package food products, but without shipping containers and various other types of packages it would be impossible to move farm products efficiently from the widely dispersed areas of production through our complex marketing system to millions of consumers. New or improved packages and containers must be developed and evaluated to do this job more effectively. Continuing changes characterize the American marketing system. In protecting, distributing and selling perishable agricultural commodities, packages and containers must respond to a number of marketing system changes. Such changes include:

- *Changes in consumer preference--from buying unpackaged items to buying in packages with convenience features such as ready-to-cook spinach.
- *Changes in distribution practices--from service grocery stores to self-service supermarkets.
- *Changes in forms of transportation--from surface to air where light-weight containers are essential.
- *Changes in handling methods and equipment--from warehouse stacks as high as a man to multi-pallet stacks.
- *Changes in protective services--from water ice to vacuum cooling, which permits use of cheaper containers.
- *Changes in market organization--from buying at terminal auction to buying f.o.b. shipping point, which permits the economies of jumble-packing instead of costly face-packing.
- *Changes in market outlets--increased emphasis on selling many agricultural products in foreign markets.

Packages and containers not only respond to changes, but changes in them stimulate improvements in other parts of the marketing system. The job of the research program in this area is to see that packages and containers keep pace with changes in the marketing system and reduce the cost of handling, transporting and storing agricultural commodities. It also seeks to improve service to consumers, promote greater sales of farm products, and increase the income of producers.

USDA PROGRAM

This is a continuing program of applied research conducted by marketing specialists, industrial engineers, and agricultural economists to (1) develop new or improved consumer packages, master containers, packing materials, and shipping containers for domestic and export marketing of agricultural products; (2) evaluate them from the standpoint of cost of materials and direct labor to pack, and their ability to reduce product damage and increase product salability; (3) determine at which point in the marketing system packaging can be done most effectively; (4) improve the efficiency of packaging methods to cut costs; and (5) investigate the needs for and benefits of container standardization and simplification. Current packaging and container research is on deciduous fruits, citrus fruits, vegetables, cut flowers, poultry and dairy products. The program is carried on in cooperation with experiment stations and industry in California, Oregon, Washington, New York, New Jersey, Pennsylvania, South Carolina, Delaware, and Florida; at field stations in Orlando, Florida; Fresno, California; and Yakima, Washington; in other main producing areas; and in the principal terminal markets. This program involves 8.6 professional Federal man-years: (a) Fruits, 2.8; (b) vegetables, 1.0; (c) cut flowers, 0.9; (d) export shipping containers, 1.8; and (e) standardization and simplification of shipping containers, 0.8.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Shipping containers and packages for fresh fruits

1. Peaches. Newly developed fiberboard and combination fiberboard and veneer wirebound boxes offer savings in materials and labor costs of 12 to 25 cents per 3/4 bushel of peaches. Bruising was reduced from 12 percent in bushel baskets to less than 6 percent in the new boxes. Peach shippers in most eastern States are shifting from veneer baskets to the new jumble-packed boxes. Adoption of these new boxes for the 30 million bushels of peaches packed in these areas should result in savings of several million dollars annually. A report has been prepared for publication.

2. Apples. Cell and tray packed Golden Delicious apples--Less costly, chipboard cell partitions, newly designed deep-pocket molded pulp trays and polystyrene foam trays were tested in comparison with conventional pulp-board trays and with corrugated partition cell pack. The new containers are cheaper than the corrugated partition cell pack.

Twelve transcontinental rail test shipments were made during the 1965 shipping season. Bruising in the three experimental packs was fairly low and well within acceptable levels. Apples packed in the conventional corrugated cell pack and the deep-pocket molded pulp tray showed the least amount of bruising. The Washington State Apple Commission cooperated in the study by furnishing the apples. A report is being prepared for publication.

Consumer packages for McIntosh apples--Newly designed, 9- and 12-count, "high-post" molded pulp trays, specifically designed to protect easily bruised McIntosh apples, were tested and compared with 3-pound polyethylene bags and 6-count molded pulp trays. The studies were conducted in a Michigan apple production area and in supermarkets in Cleveland, Ohio. The apples packed in the experimental "high-post" trays had less bruising than did those packed in the two types of conventional packages. The costs of packaging materials and packing labor per pound of apples were 3.0 cents for the experimental "high-post" trays, 1.6 cents for the polyethylene bag and 3.3 cents for the 6-count tray. A combination display of 3-pound polyethylene bags and 9- or 12-count "high-post" trays sold more apples than a combination display of 3-pound polyethylene bags and 6-count trays. However, the difference in sales was not statistically significant. A report is being prepared for publication.

3. Pears. Consumer packages for winter pears--A report was prepared covering the results of 4 years' research on the development of consumer packages and master containers for pears prepackaged at shipping point.

4. Grapes. Four truck and one rail test shipments were made to test a new full-telescope wax-coated fiberboard container in comparison with the commonly used wood display lug. The grapes packed in the fiberboard boxes had an average of 1.2 percent bruised, 1.9 percent shattered, and .6 percent split berries and those packed in the conventional wood lug had 2.5 percent bruised, 1.3 percent shattered and .7 percent split berries. The reaction of the wholesale and retail trade was generally favorable but some persons pointed out that the boxes were slippery and required more care in stacking.

The fiberboard box did not hold up as well in cold storage as did the wood lug. The fiberboard boxes required special pallet supports and, by the end of March, many containers had excessive bulging and sagging.

5. Citrus Fruits. Florida Temple oranges were packed in consumer packages in production areas and shipped to eastern markets during the 1964-65 season. Of the various types of chipboard, plastic and molded trays tested, a purple, molded pulpboard tray holding six 100-size oranges, sleeve-wrapped with a polyvinyl chloride heat-shrinkable film, appeared to be the most promising package. Trade reaction to this package was favorable. Cost of materials and labor for packaging was 5.7 cents--about 2-1/2 times the cost of packing oranges in conventional 4/5-bushel containers.

B. Shipping containers and packages for vegetables

Pole beans. Four types of consumer packages were evaluated for prepackaging Florida fresh pole beans at shipping points. The packages evaluated were (1) a green 1-1/4-pound molded pulp tray sleeve-wrapped with a heat-shrinkable film, (2) a transparent 1-1/4-pound plastic tray sleeve-wrapped with a heat-shrinkable film, (3) 1-pound polyethylene bags, and (4) 1-1/4-pound polyethylene bags. The packaged pole beans outsold bulk beans

during a four-week retail sales test. Sales were greatest in the 1-1/4-pound plastic tray. The packaged beans remained green and turgid, and their shelf life was one to three days longer than that of the bulk beans.

The cost of packaging materials, labor and transport for 28 pounds of good quality pole beans packed in the four experimental packages in Florida production areas and shipped to New York City ranged between \$2.56 and \$2.84. Of the four packages, the 1-1/4-pound transparent plastic trays were the most expensive and the 1-1/4-pound polyethylene bags, the least expensive.

Trade acceptance of the packaged pole beans was very favorable. About 16,000 master containers of the prepackaged fresh pole beans were shipped during the 1964-65 season.

The field work was completed during the 1964-65 season. A report is being prepared for publication.

C. Shipping containers for cut flowers and potted plants

Costs of containers and accessory packaging materials now being used were obtained and the labor required to pack various containers was measured. Air freight rates and packed shipping container densities have been analyzed to determine the effect of a newly designed lightweight one-piece shipping container on freight costs. Container manufacturers were consulted about the possibilities of developing cheaper containers.

D. Containers for overseas movements of fresh fruits and vegetables

1. Apples. A research contract was negotiated with Rutgers University for determining the acceptability of one of the proposed Organization for Economic Cooperation and Development (OECD) International Standard Apple Containers to the United States Apple Industry. The contractor will determine the cost and physical feasibility of packing and shipping Golden Delicious and McIntosh apples in uniform fiberboard cell-type shipping containers having outside dimensions of 50 x 30 cm. This is the only OECD container with length and width dimensions close to those in this country. Several dimensional size cell containers are now used for Golden Delicious and McIntosh apples. It is expected that the packing of all different count sizes of apples in one size container would waste some space thereby increasing container costs.

2. Pears. The feasibility of exporting winter pears in fiberboard boxes was studied in the 1964-65 season. D'Anjou pears were packed in the conventional standard wood box and in less costly experimental full-telescope fiberboard boxes with molded pulp trays. Half the fiberboard boxes were modified by a corrugated fiberboard collar stapled around the top of the outer case to assure air channels between stacks.

Pears packed in the test boxes were held in a commercial cold storage for three months. Four test shipments of the same pears were made from Portland, Oregon, to London, England. Upon arrival in London, the pears packed in the fiberboard boxes had no damage or serious bruising and had significantly less slight bruising than those packed in standard wood boxes. The latter averaged 2.5 percent damage bruising and .6 percent serious bruising. Both containers arrived in good condition.

The pears packed in the wood boxes cooled faster in cold storage and warmed up faster in the warmer refrigerated ship's hold than those in the fiberboard boxes. A report on the work completed is being prepared for publication.

3. Grapes. Emperor grapes packed in four types of shipping containers were shipped from California to London, England. The containers studied were: (1) The conventional 34-pound sawdust chest, (2) the 22-pound sawdust chest, (3) 21-pound wood lugs with grapes packed stem up, and (4) the conventional display lug packed with 24 pounds of grapes. The 34-pound chests were individually strapped. The other three containers were strapped in bundles of two. Thirty 34-pound chests and thirty-six 21-pound lugs were strapped to pallets.

The costs of packaging materials per pound of grapes were as follows: 34-pound sawdust chest individually strapped, 2.9 cents; palletized 34-pound sawdust chest, 3 cents; 22-pound sawdust chest strapped in bundles of two, 2.8 cents; 21-pound lugs strapped in bundles of two or strapped to pallets, 2.2 cents; and the 24-pound display lug strapped in bundles of two, 2.2 cents.

The grapes packed in the test containers were all in good condition upon arrival in London. The appearance and condition of the grapes in the 34- and 22-pound sawdust chests were best, followed by those in the 21-pound lugs and the 24-pound display lugs. The grapes in the palletized containers were in better condition and had better appearance than those in the non-palletized containers. The wholesale and retail trade in London expressed a desire for a better pack than any of the four tested.

One commercial shipment of California Emperor grapes packed in 27-pound display lugs was shipped by rail to New York and then by ship to London. Two of the 20 lugs were smashed during unloading. After 30 days in transit, the grapes showed 3.7 percent shattered, 1.5 percent split, 1.6 percent flattened, and 1.7 percent decayed.

4. Citrus:

Grapefruit. Two commercial shipments of Arizona grapefruit packed in metal-strapped full-telescope fiberboard boxes shipped from New York to London arrived in the following condition: (1) 7.2 percent discolored, (2) 11.4 percent bruised, (3) 1.5 percent crushed or punctured, and (4) 2.5 percent decayed.

Lemons. Two test shipments of California lemons packed in metal-strapped full-telescope fiberboard boxes shipped from New York to London arrived in the following condition: (1) No skin discoloration or bruising, (2) 1.8 percent soft, and (3) 1.0 percent decayed.

5. Avocados. Five commercial shipments of three types of containers packed with avocados shipped from New York to London were examined. The three container types studied were: (1) Fiberboard boxes with molded pulp trays (2 tests), (2) wood flats with wood excelsior pads (1 test), and (3) combination wood and fiberboard flats with molded pulp trays (2 tests).

In the first two shipments, the fiberboard boxes were strapped in bundles of two flats with metal straps. Upon arrival in London, almost all the fiberboard boxes were damaged by the straps. The condition of the avocados was rated as "good" They had no decay but had an average of 1.0 percent bruising and 5.5 percent slight discoloration.

The avocados in the third shipment were packed in wood flats. The boxes arrived in London without damage. The condition of the avocados was rated as "good" with no decay and 10 percent slight discoloration and 4.0 percent slight bruising.

In the last two test shipments, the combination wood and fiberboard flats arrived in London without container damage. The avocados were mature when they arrived in London and were rated in "fair" condition.

In the fourth shipment, the avocados showed 12.5 percent slight discoloration, no bruising, and 2.5 percent decay. In the fifth shipment, they were 100 percent discolored and 4.0 percent bruised.

6. Celery. Exploratory work on a project planned to improve the condition and salability of celery upon arrival in foreign markets was initiated during the 1964-65 season in cooperation with Florida growers and shippers. In an effort to reduce mechanical injury, moisture loss, leaf discoloration and other types of product damage to celery, the following experimental packages were tested in three shipments to London, England: (1) Celery stalks packed in 1-mil polyethylene bags; (2) conventional bulk-packed crates, some lined with 5-mil polyethylene film and some lined with 2-mil polyethylene film; and (3) flat pack--the conventional crate packed without a bulge. The standard bulge-packed crate with parchment liner was used as the control.

The celery packed in all the test treatments was acceptable upon arrival at destination. Mechanical injury observed was slight and no discoloration of the stalks was apparent in any of the test containers. Although they reduced moisture loss, the polyethylene film liners created relatively high moisture conditions inside the crates.

Total materials costs for packing 48 stalks of celery in polyethylene bags were 87 cents compared to 43 and 47 cents for the crates lined with 2-mil and 5-mil polyethylene film, respectively. London receivers objected to paying for the added cost of prepackaging the celery in polyethylene bags.

7. Bell peppers. Five commercial shipments of peppers, three place-packed in wirebound crates, one jumble-packed in wirebound crates, and one jumble-packed in wax-impregnated fiberboard boxes, were examined on arrival in London. The peppers in place-packed wirebound crates, after 9 to 13 days in transit, arrived in London with low and acceptable levels of mechanical injury and decay. The jumble-packed peppers in wirebound crates in the fourth shipment required 12 days' transit time from New York to London and they arrived in poor condition. In the fifth shipment, the peppers were jumble-packed in wax-impregnated boxes and they arrived in London in poor condition with 3 percent bruised and 8 percent decayed. Container damage was very slight in all shipments.

8. Dry onions. One pilot test shipment of Texas mild, dry, spring onions was made by ship from Texas to Rotterdam and trans-shipped to England. Twenty 50-pound mesh bags and two mesh bags containing fifteen 3-pound polyethylene net bags were included in the shipment. The onions were subjected to rough handling and many of them were bruised. Between 30 and 60 percent of the onions were skinless on arrival in England.

9. Air shipments to Europe. Three shipments of fresh vegetables, fruits and cut flowers were shipped by air freight from U. S. production areas to a U. S. Trade Fair Show in London. The items shipped included papayas and orchids from Hawaii; prepackaged iceberg lettuce, asparagus, artichokes, limes and cut flowers from California; green onions from Arizona; Boston lettuce from Indiana; and prepackaged celery, pole beans, yellow squash, corn and strawberries from Florida. Each commodity was shipped in the lightest container available. The commodities arrived in excellent condition and had good shelf life when displayed in a refrigerated display case. Representatives of the produce and flower trades in England expressed interest in all the products shown.

E. Standardization and simplification of containers for fresh produce

A research contract was negotiated with the Research Triangle Institute for a pilot study on the characteristics and extent of use of shipping containers for marketing fresh fruits and vegetables. The objectives of this study are to:

- (1) Secure basic data on the dimensional sizes and extent of use of containers for marketing fresh fruits and vegetables.
- (2) Provide the Statistical Reporting Service accurate data on the net weights of packed containers for conversion of shipment records into quantitative amounts that are used for checking production estimates.
- (3) Provide a basis for increasing the efficiency of marketing fresh fruits and vegetables by selection and use of a smaller number of containers that can be more efficiently used on standard size pallets.

(4) Secure data on the dimensions and use of containers in the United States for dissemination and discussion at international meetings concerned with the development of international standards for containers used in international trade.

The survey is being made in four produce warehouses in Los Angeles and four warehouses in New York. The work began in July 1965 and is scheduled for completion in September 1966.

PUBLICATIONS REPORTING RESULTS OF
USDA AND COOPERATIVE RESEARCH

Fruit

Mallison, Earl D. 1965. Shipping Containers for Peaches. Paper presented at the annual meeting of the Georgia Peach Council, Griffin, Georgia. Jan.

Vegetables

Stokes, Donald R. 1965. Packaging California Potatoes. Paper presented at the 21st Annual Convention, Potato Growers Association of California, Bakersfield, California. Mar.

TRANSPORT EQUIPMENT AND TECHNIQUES

Transportation and Facilities Research Division, ARS

Problem. The cost of transporting farm products to market in 1964 was about 5 billion dollars. Cost of transporting supplies used in farm production was more than one billion dollars. Further, costs of other marketing and production functions, such as loading and unloading vehicles, packaging, storage and processing, also are affected by the efficiency of transport. These costs are important to the American farmer because they influence the return he receives from the sale of his products. They also are important to the American consumer because they influence the price he pays for his food. Therefore, the prosperity and efficiency of our entire agricultural industry and the economic well-being of the American consumer are closely tied to the efficiency of our transport system.

In spite of the importance of transport to agriculture and the consuming public, research to make it more efficient and less costly has been meager. New advances in transport and engineering technology, including the development of new materials, new building and operating techniques for transport equipment, containerization and unitization--all offer opportunities to improve agricultural transport. Translating these and other opportunities into working advantages for our agricultural producers and consumers requires a strong program of economic-engineering research. Such a program will help increase returns to American farmers, provide better products and lower costs to American consumers, and improve the competitive position of our farm products in foreign markets.

USDA PROGRAM

The economic-engineering research in this field is a long-range program. It seeks to develop improved transport facilities, equipment and techniques and more efficient ways of using them in transporting agricultural products and supplies. It is interdisciplinary in nature, drawing upon the training and experience of economists, mechanical and industrial engineers, marketing specialists and various other scientists. All the work is done with the cooperation of transport firms, transport and refrigeration equipment manufacturers and lessors, trade associations, State universities and experiment stations. Field studies are carried out throughout the U. S. and on overseas shipments. Only one field station, Orlando, Florida, presently is maintained to support this research program. Part of the work is accomplished through research contracts and cooperative agreements.

At the present time, work is underway in each of the following fields: (1) Transport equipment, (2) refrigeration equipment and techniques, (3) better utilization of transport equipment and techniques, (4) loading methods, including unitized and palletized loading, and (5) overseas transport.

This program of research involves 11.7 professional man-years apportioned as follows: Transport Equipment 4.2 and Transport Techniques 7.5.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Transport Equipment

1. Flower Transport. Growers in Florida and Colorado were surveyed to determine the transport problems and some possible solutions. Results of this exploratory research will be used in planning the experimental phases of work to improve the transport of flowers. Observations were made on shipments of cut flowers by refrigerated trailer from Florida to New York.

It was found that pompons and gladioli were carried at temperatures of 45°-55° F. instead of at the desired level of 35° F. The higher-than-desired temperatures were caused by a combination of too high thermostat setting and inadequate air distribution within the trailer. Additional tests are planned to find ways of providing more desirable transit temperatures.

Other facets of the flower transport system to be studied include precooling of flowers before shipment, increased loading density, control of the oxygen level with nitrogen or carbon dioxide, unitization of loads, and elimination of delays at transfer points.

B. Transport Techniques

1. Pallet Containers for Transportation. All field work has been completed, the data analyzed and results evaluated on rail and truck shipments of apples in both expendable and reusable pallet containers of several different types. The initial report was extensively revised and reviewed for publication. This project will be terminated during the coming year.

This research has shown that savings from using pallet containers of about 900 pounds capacity as compared to conventional 40-pound corrugated boxes range from 0.1 cent per pound, or about \$150.00 per carload for one trip to 0.2 cent, or approximately \$300.00 per car when the pallet containers are used for two trips. For some types of pallet containers, greater savings may be made by using them for three or more trips. The economies in pallet container usage in transport result from lower container, packing, handling, freight and protective service costs per pound of fruit.

2. Loading Methods for Potatoes. Five air-flow loading patterns were developed to improve air circulation in motortruck shipments of bagged potatoes by providing a number of continuous longitudinal channels through the load. Tests results showed that when the trucks operated at approximately 50 miles per hour under ventilation, the average velocity of air movement in the circulation channels ranged from 141 to 274 feet per minute. Air velocity over the top of the load ranged from 280 fpm to 472 fpm. Air movement through the channels caused temperatures throughout the load to

change directly with the outside air temperature. The air moving through the channels also made it possible in some instances to remove excess moisture from damp potatoes. The new patterns are easy to load in any size vehicle and provide the trucker a full payload with proper weight distribution. The patterns are stable and remain intact during transit and do not increase container or product damage.

The final report on this research has been published and the project terminated.

3. Heavier Loading of Watermelons. All field work has been completed, the data analyzed and results evaluated on all-rail and rail-piggyback shipments of long-type watermelons loaded 6 and 7 layers high compared with the conventional 4- and 5-layer loads. Additional data on freight costs were developed during the year and integrated with previously developed information on product damage, cooling rates and loading costs. The initial report was revised and reviewed for publication. This project will be terminated during the coming year.

This work demonstrated that shippers can take advantage of multiple-minimum or per-car rates to reduce transport costs through heavier loading provided proper precautions are taken to load only sound, disease-free melons of uniform size and shape. It was found that rail-piggyback shipments may be loaded 8 and 9 layers deep with substantially less melon damage than standard rail car shipments loaded only 6 and 7 layers deep. The use of piggyback trailers for delivery of melons to retail outlets has increased the flexibility of marketing, reduced handling costs, product damage and eliminated temporary storage of melons in wholesale warehouses and transport vehicles.

4. Loading Methods for Fresh Peas. The results of this study show that continuous stave baskets and the alternately inverted loading pattern can be used to reduce the amount of physical damage during rail transport. However, less refrigeration is obtained from top ice on the load when the crosswise offset pattern is used. Damage was also reduced and product refrigeration was not impaired when the amount of top ice was reduced by about half and half-stage bunker icing was used.

The report on this research was revised and reviewed for publication. This project will be terminated during the coming year.

5. Loading Patterns for Bagged Onions. More than 100 rail shipments of bagged onions from producing areas in Texas to eastern and midwestern markets were studied to obtain additional information on a new air-flow loading pattern developed in previous research. The new load pattern provides more and larger channels which permit air to move freely through the load. More of the air coming into the refrigerator car circulates through the load to help remove excess heat and moisture. This helps to prevent development of decay. One shipper adopted the new loading method for all his shipments which totaled more than 100 carloads. It is anticipated that other shippers will adopt the new method next season.

All field work has been completed. The data will be analyzed and results evaluated, and a detailed report prepared for publication during the coming year. This project will be terminated during the coming year.

6. Loading Patterns for Fiberboard Citrus Boxes. A modified bonded-block stacking pattern for corrugated fiberboard boxes in truck-trailers was developed and tested for three shipping seasons. The pattern provides inter-connecting channels throughout the load to allow air circulation to each box of fruit. Air circulation through the load was improved in both ventilated and refrigerated shipments. Product temperatures were maintained nearer the recommended levels during transport. The new pattern is easy to load and is adaptable to any size trailer. Good row and stack alignment are maintained during transport, and commodity and container damage are held to a minimum. It is estimated that more than 90 percent of all Florida oranges and grapefruit packed in the 4/5-bushel corrugated box are stacked in this way for transport by truck and rail piggyback.

A report on this research has been submitted for publication. This project has been discontinued.

Fruits and vegetables--Two shipments of fresh grapefruit were made from Florida to markets in France and West Germany in non-refrigerated van containers. The ventilated shipments moved via highway, rail, and ship in an integrated land-sea-land transport system. An average ship speed of 24 miles per hour during the ocean portion of the trip, and reduced loading and unloading time, made it possible to deliver one shipment to Paris in 15 days and the other shipment to several destinations in Germany in 16 days.

Each of the 40-foot containers arrived with no pilferage of or physical damage to the fruit. Receivers in both countries were impressed by the freshness of the fruit and the speed of transport. Conventional transport methods require from three to four weeks for fruit shipments from the U. S.

The tests demonstrated that less expensive ventilated service can be used for containerized shipments of grapefruit to European markets when the weather is cool enough and that 40-foot container vans can be transported on principal highways in some European countries without difficulty.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Transport Techniques

Hinds, R. H., Jr., and Robertson, J. K. 1965. Airflow Loading Patterns for Truck Shipments of Early Potatoes. Agricultural Research Report 689, 12 pp. Mar. 1965.

RETAIL FOOD STORE OPERATIONS

Transportation and Facilities Research Division, ARS

Problem. There are about 325,000 food retailing establishments in the United States which market over two thirds of all farm products, representing nearly \$68 billion of sales. Of these there are 228,000 grocers carrying a complete line of food. The cost of retailing is over \$10 billion annually and requires about 15 percent of the consumers dollar spent for food. The labor costs alone in these stores represent approximately \$5 billion a year for the nearly 2 million employees.

A number of developments accelerate the need for more research in this area. Increasing wage rates, especially with pending minimum wage legislation as well as rising costs for real estate, construction, equipment and materials, require constant improvement in management if retailing costs are to be held down. The number of food products carried by retail food stores is steadily increasing. Thus, competition of items has lowered individual product volume and increased item costs. The competitive pressures of new supermarkets has decreased the number of customers served per store and lowered sales per square foot of space, also adding to costs. As a result rising costs are no longer offset by increasing efficiency. The Food Marketing Commission has pointed to increasing margins in the food trade.

Drastic changes in operating procedures appear to be necessary to offset the rising cost of retailing. Most firms are too small to afford expensive research or trial and error experimentation. Others need to be shown that research is effective. Indiana independent food retailers provide an excellent example of what can be done by this research. Indiana was the first state to adopt a program for working with retailers and through the State Extension Service has applied much of the previous research of this Branch. As a result gross margins for the Indiana independent food retailers applying the research results have increased only 7 percent since 1955, whereas chain stores report an increase of 22.7 percent.

USDA PROGRAM

The Department has a continuing long range program of research utilizing marketing specialists, engineers and personnel with other skills to develop improved work methods, equipment, materials, layout and operating procedures for retail food firms. This work is carried on an informal cooperative basis with Federal and State Extension Services, other governmental agencies, State Departments of markets, trade associations, and with members of private industry. Contracts are used for some projects and some research grants are received from private industry. The program includes the utilization of various means of disseminating the information to the separate firms by such tools as motion pictures, clinics, speeches, and similar means.

The federal professional man-year effort devoted to this research in 1964-65 totaled 2.6 years, and of this number 0.7 man-year was devoted to produce, and 0.2 man-year was devoted to store operations and facilities.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Preparation and packaging of produce at the central warehouse. The purpose of this project is to improve and evaluate the cost of central warehouse produce packaging and to make comparisons with other locations for produce packaging. Retail food stores annually sell about 4 billion consumer units of bagged potatoes, citrus, apples and onions. There is a potential savings of over 100 million dollars through receiving these items in pallet type containers and packaging them at the central warehouse with improved methods and equipment. This could result in a 2.8 cents savings per unit to the consumer.

The most desirable size pallet box for shipping and receiving produce is 42 x 47 inches and varies from 23 inches in depth for apples to 30 inches for potatoes. This size will hold from 800 to 1300 pounds of produce. Labor requirements are reduced as much as 91 percent for warehouse receiving and 66 percent when the contents of pallet boxes are dumped directly on the packaging line.

A returnable master container is essential to delivery of centrally packaged produce. For bagged products the container should hold 60 pounds of product, nest and stack, fit on warehouse pallets, be light weight, easily cleaned, utilize space effectively, handle a variety of product, be an integral part of the firm's overall delivery system and have a long use life. A thermoplastic container weighing about 6 pounds which nests and stacks and has about a five-year life was the lowest cost container tested.

Scheduling and cost control were necessary to low operating costs for central warehouse packaging. Two systems for cost control were developed: a manual system, and a program for electronic data processing.

In an overall cost comparison of packaging at different locations, including the cost of shipping containers, freight and labor, the lowest cost location was at the central warehouse. There is a potential savings of over \$100,000 per year in a central warehouse which has an average volume of 70,000 units per week.

The costs of preparing bananas for sale and of product shrinkage during display are lowest when the bananas are wrapped in a sleeve of heat shrinkable film at the central warehouse. A firm which sells 3,000 boxes per week would save \$67,000 over tape banding at the store with typical methods.

A Marketing Research Report entitled "Produce Packaging at the Central Warehouse - Bagging" has been prepared and is being printed. A second report entitled "Produce Packaging at the Central Warehouse - Bananas" has been prepared and is in Department clearance. A third report, "Produce Packaging at the Central Warehouse - Trayed Items," has been prepared in draft form.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Hoecker, R. W. 1965. Trends in Servicing Retail Stores. Paper presented at the Third Annual Citrus and Vegetable Marketing Clinic, Lakeland, Florida. May. (Processed)

Anderson, Dale L. 1964. The Centralization of Retail Processing. Paper presented at the United Fresh Fruit and Vegetable Association Convention, Chicago, Illinois. Sept. (Processed)

COOPERATIVE MARKETING

Farmer Cooperative Service

Problem: Farmers continue to increase their use of cooperative marketing.

These cooperative operations are conducted in a marketplace where handling and processing, transportation, and distribution technology is changing rapidly, and market organization and practices are undergoing major changes. Farms themselves have changed. Farmers and their cooperatives need research results that relate to these developments and new conditions to assist them in marketing efficiently. Such research will assist farmers to strengthen their bargaining power, increase marketing efficiency, and meet effectively the quality, quantity, and service needs of today's food and fiber marketplace.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

Federal professional man-years devoted to research in this area totaled 19.6. Of this number, 0.9 was devoted to citrus, 1.4 to deciduous fruits, 1.2 to potatoes, and 1.5 to vegetables.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Most of the commodity marketing research of the agricultural experiment stations is helpful to marketing cooperatives. Some projects, however, deal specifically with cooperative marketing problems, opportunities, and impacts. At the present time 10 States have 12 research projects in cooperative marketing. Their commodity distribution is as follows: grain-2, tobacco-1, fruit and vegetables-1, livestock-2, and cross-commodity-6.

Some projects evaluate the performance and organizational features of cooperatives. Different methods of pooling and their problems are studied so as to develop helpful principles. In the analysis of cooperative operations and in working with directors and managers, efforts are made to identify and solve the many problems that are arising. Particular attention is given to what services or functions should be provided by cooperatives. There is interest in learning more about the attitude of members and nonmembers toward cooperative marketing, especially the differences in these attitudes.

In the last few years more attention is being given to the role of cooperatives in achieving bargaining power for farmers. In connection with market structure studies, special attention is being given to the impact of cooperatives on market conduct and performance.

The total research effort on cooperative marketing in the 10 States is 2.5 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Coordination of marketing

Farmers and their cooperatives need to adapt their marketing methods to the requirements of large-scale buyers, mass merchandising, and other changed conditions. In many cases the coordination of marketing of a number of cooperatives, marketing the produce of hundreds or thousands of farmers is needed to satisfy these needs and improve returns to farmers. Such coordination may be accomplished by establishment of joint sales agencies or by other methods. Research to determine the problems and needs, and to develop guides for adopting new practices, included work with several commodities.

A study in depth of the organizational characteristics and operating methods of selected marketing agencies which have successfully marketed fruits and vegetables for member associations on a joint basis is continuing. Problems and possibilities of these associations are being evaluated and guides will be developed for other cooperatives interested in a coordinated marketing program.

A study is underway of the feasibility of the merger of two Northeast cooperatives that market potatoes and purchase farm supplies for growers.

B. Improving cooperative sales, distribution, and pricing methods

Wholesale and retail marketing practices are continuing to change rapidly, and there have been fundamental changes on the farm. For these reasons sales and distribution and pricing methods need to be studied carefully to plan and realize methods and policies that are technically efficient and obtain good returns for producers. Bargaining methods and pooling are two topics that require major research emphasis. Research on these problems included work in several commodities.

This research seeks to appraise the status, role, and potentials of cooperative bargaining as a means of stabilizing and enhancing the incomes of producers of deciduous fruit and tree nuts, and vegetables.

Research to determine the impact of the 1962 Florida freeze on pooling practices has been completed. This study shows growers' on-tree returns were higher, and crop losses were lower, where their marketing cooperative had a large volume operation supported by adequate harvesting equipment and an established processing affiliation. Grower benefits were maximized under

the single pool arrangement which allowed management flexibility in marketing the crop regardless of end product use, and under an adjusted method of dispersing pool returns which allowed the largest, most accessible and least damaged groves to be harvested first with pools adjusted for any unpicked fruit. This research was conducted under contract with the University of Florida.

Analysis continued of ways for selected cooperative marketing dry edible beans and peas to improve their marketing and distribution effectiveness. This work was conducted under contract by a private research organization.

A study of retail chainstore and wholesale produce buyers' preferences for celery was completed. These buyers pointed to the need for adequate volumes of uniformly high quality product backed by a well-organized promotion and sales effort. This study was conducted under contract with a private market research firm. Research findings have been published by Farmer Cooperative Service.

C. Potentials in cooperative marketing

The present and potential role of cooperative marketing requires study in several commodity areas. Current information on cooperative operations can be related to production and marketing conditions. The objective of such research is to develop recommendations about operations and services of existing cooperatives and particularly to identify opportunities for farmers to increase their marketing returns by developing significant new areas of cooperative operation.

A nationwide study is underway to obtain basic data for an analysis of present status and trends in the cooperative marketing of fruits, vegetables, and nuts. This study also seeks to evaluate the potential of cooperatives for increasing their operating efficiency and market effectiveness through integration, coordination, consolidation, expansion, or other means.

Studies were made of cooperative fruit marketing and storage operation potentials in New Mexico and New York and technical assistance on organizational structures, and plans of operation were developed.

A study was initiated to determine and evaluate the role of cooperatives in the market structure of the major potato producing areas of the United States. The study seeks to examine market conduct and performance and the cooperative form of enterprise as an influence on structural dimensions, efficient marketing, and the improvement of farmers' income. This intensive study of potato marketing supplements data on potato marketing obtained in the nationwide study of status and trends in fruit and vegetable marketing.

A study was made of a proposed chile processing facility in New Mexico. It was determined that the economic prospect for processing and marketing chile was such that any cooperative venture in this area would be attended with high risk.

D. Improving operating and handling methods

Research was underway in several commodity fields to examine new methods, equipment, and structures for efficient and safe processing and storage of agricultural products by cooperatives.

Work continued on a study to determine the nature and extent of large-scale buyers' requirements -- particularly those made on a specification basis -- for Florida fresh citrus.

A study of wholesale buyers' practices and preferences for Virginia white potatoes was completed and a report covering the findings of the study was published. The study showed that Virginia growers and shippers may improve their industry position by adhering to more strict grading and sizing of product and by initiating programs for more orderly marketing. This study was conducted jointly by Farmer Cooperative Service and the Virginia State Department of Agriculture.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Berberich, R. S. 1964. Considerations in Establishing a Fruit Storage and Marketing Facility and a Chile Processing Plant in the Espanola Valley, New Mexico. FCS Service Report 70.

Blum, M. A. 1965. Stress Marketing Performance for Fruits and Vegetables. News for Farmer Cooperatives (Jan.).

Blum, M. A., and Meyer, C. H. 1965. Attitudes of Wholesale Buyers Toward Florida Celery. FCS Service Report 72.

Proceedings of the 9th National Conference of Fruit and Vegetable Bargaining Cooperatives. FCS Unnumbered Report. 1965.

ORGANIZATION AND PERFORMANCE OF MARKETS

Marketing Economics Division, ERS

Problem: Economic research in agricultural marketing revolves around the problems of increasing efficiency in the processing and distribution system and providing a foundation for orderly adjustments to changes inside and outside of agriculture. Marketing must be looked upon as a dynamic and changing process. The capacity to adjust to and cope with the dynamics of modern marketing is required increasingly of producers and distributors of farm products. Demands of a more knowledgeable and sophisticated consuming public are adding to the pressures for an even more rapid escalation of developments and changes within the marketing system. Changes in institutions and redirection of public policies and programs are modifying the economic environment in which marketing firms must perform and operate. Because of rapid changes and increasing complexities associated with a dynamic marketing system, it is necessary that a continuous program of research be conducted in marketing--a program aimed at keeping producers and marketing firms abreast of the flow of events and providing information necessary to them in making proper and orderly adjustments to change.

Research in the area of organization and performance of markets is designed to find solutions to economic problems of marketing, including the transportation of farm products. This involves economic studies of: Size, ownership, financing, structure and practices of marketing firms; measurement of farm-retail spreads; cost of marketing and allocation of costs and charges among agencies and functions; resources used in marketing; measurements of growth and labor productivity; demand for and supply of food marketing services; pricing of products and services; interregional competition; and farmers' bargaining power. Economic studies of transporting farm products include: Determining patterns of product flow that will maximize returns to farmers and minimize costs to consumers while taking into account the needs of carriers, factors affecting carrier costs and charges for moving farm products and supplies, impact of technological changes in transportation services and facilities upon product flows and optimum locations of processing facilities, industries, etc.

Such studies furnish a basis for adjusting to change and keeping abreast of technological and scientific developments. Likewise, the studies provide a sound basis for both private and public policy decisions as they relate to marketing.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program of economic research designed to increase the efficiency of marketing and assist producers and marketing agencies in adapting to a changing environment. Research is conducted on a wide range of functional and commodity problems that arise in moving farm products from producers to consumers. The program involves both basic and

applied research and is primarily oriented to problems of national and regional scope. Field studies are often conducted jointly with State agricultural experiment stations, with processors and distributors of agricultural products, transportation agencies, and agriculturally-oriented trade groups. Producer groups and trade organizations have, with increasing frequency, made financial contributions to the Division research efforts. Many staff members are working closely with the staff of the National Commission on Food Marketing in a consultative role and in research studies on price spreads and market structure. These studies are partly financed by the Commission.

The Department's program of research and related reporting activities are conducted from headquarters in Washington, D.C., with a limited number of field stations located throughout the United States. In addition to conducting research, field station personnel perform a special service in keeping the Division alerted and informed on emerging and significant problems in marketing.

In the overall area of organization and performance of markets, the scientific effort devoted to this research in the past year amounted to approximately 78 professional man-years. By functional subareas the research effort in professional man-years was distributed as follows: Market institutions and market power, 26; prices, costs, and margins, 40; and, location and interregional competition, 12.

PROGRAM OF STATE EXPERIMENT STATIONS

A. Market Institutions and Market Power

Changes in the structure of marketing agricultural products affects the bargaining power of buyers and sellers. These changes also affect marketing practices, services and prices--and ultimately producers, marketing firms and consumers. Research underway at the State stations deals with these changes and some possible alternatives.

Fifteen studies in 13 States are concerned with the direction and magnitude of major changes in firm organization, economic forces, policies, and practices influencing changes in marketing grain and the relationship between economic forces and policies, and the trends in market structure. Information on consolidation, integration, mergers, and their consequences, along with decision-making processes, is being sought. Information on the magnitude and future course of changes would help in expediting and directing feasible trends. Recent extension of operations of many marketing firms toward both sources of supply and product distribution may be materially

Nine station projects in horticultural specialties are in progress. Six are on floricultural products of which five are contributions to NEM-8. This project is studying the economic problems in marketing floricultural products in mass market outlets. This involves analysis of the existing situation, practices in procurement, handling and selling, and evaluation of potentials, including impact on growers, wholesalers, and retail florists. An investigation in the southern region is directed at requirements of local retail florists as to sources of products and material and transfer costs.

Three studies on ornamentals are underway. Two are in the southern region and are studying marketing channels used and price-quantity relationships for the foliage plant industry, and movement of products through the market, sources of supply, destination of shipments and relationships among firms in the market. One study is of the Hawaiian nursery and landscape industries as to practices followed, growth potential, and financial requirements. A total of 5.5 professional man-years at the State experiment stations is involved.

Much of the research at the State agricultural experiment stations on fruits and vegetables relates to structure, practices, and market performance. Much of the research relates to trends in market structure and practices, causes of such trends, the extent to which producer and wholesaler practices meet the needs of large-scale buying by retailers, development of suggested organizational structure which will increase marketing efficiency and returns to growers. A total of 17.8 professional man-years is devoted to this area of work.

B. Prices, Margins and Costs

Prices and marketing margins are continually being examined in light of changes in production, processing, storing, transporting, and distributing agricultural products. Historically, retail prices have increased relatively more than farm prices, which is a reflection of increased marketing services of many products. There is a high degree of public and legislative interest in this research being conducted by the State stations.

A study in the Pacific Northwest is analyzing market price trends for dry edible peas, and factors useful in predicting market quantities and prices. Another study is concerned with an evaluation of supply, demand, and prices for certified seed crops, and effects of methods of marketing and competitive bargaining situation on the level of prices received. A total of 1.6 professional man-years is involved.

Two stations have projects in the horticultural specialties area. One study is concerned with factors which influence retail nurserymen in their purchasing of woody ornamentals, and a determination of the relationships among landscaping service, nursery retail sales, and other business aspects of firms in the nursery industry. The other study is to determine costs of grading flowers and the differences in returns between graded and ungraded flowers. A total of 1.0 professional man-year is involved.

C. Location and Interregional Competition

Changes in the technology of producing and processing agricultural products has much impact on the comparative advantage of one producing area over another. Changes in transportation rates and costs also affect the competitive position of some areas more than others. These changes and their effects on the location and interregional competition are being studied by the State stations.

Since grain marketing and processing facilities require extensive capital investments and can be used for few other purposes, correct decisions relative to type and location are important. Sixteen studies concerned with transportation and location of grain marketing facilities are underway. Most of these studies contribute to regional undertakings. The researchers in the north central and southern regions have exchanged information and are coordinating their research to maximize the efforts of both regions. Some of the work in this area is closely related to the research reported under Market Institutions and Market Power.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Market Institutions and Market Power

The structure of markets for agricultural products is changing in many dimensions and the market power of buyers and sellers and practices of marketing firms are shifting in response. All these changes have significant impacts on farmers, consumers, and marketing agencies. The Marketing Economics Division conducts studies on many phases of this changing market.

Direct purchasing of fresh fruits and vegetables by retail chains has affected the market for fresh produce. Approximately 26 percent of the total receipts of fresh produce in 52 markets in 1958 were direct purchases from shipping points by retail chains. An intensive study of the Philadelphia wholesale market has been conducted to determine whether the proportion of direct purchases increased from 1958 to 1964 and to appraise the effects of a new food center on the marketing channels and practices in a major wholesale market. Preliminary indications are that the number of wholesalers in Philadelphia decreased from 207 in 1958 to 160 in 1964.

Changes in wholesale marketing of fruits and vegetables have been accompanied by changes in shipping point markets. These changes have been studied in the winter-vegetable producing areas of Florida, Texas, and California. Studies of marketing of vine ripened (or pink) tomatoes from Florida have shown that the grades for these tomatoes are inadequate in the view of many members of the wholesale trade.

Fruits and vegetables comprise 33 percent of the tonnage of agricultural commodities shipped out of California. About 30 percent of this tonnage was hauled by motor freight. New and improved packing methods for peaches and nectarines have been devised. The tight-fill pack promises savings, in packing, of 18-25 cents per Los Angeles lug equivalent.

Changes in methods of selling have raised questions of market performance and the equity of producer returns. Studies in the Rio Grande Valley of Texas indicate the market for tomatoes, citrus, and carrots behaves competitively and that chain stores pay prices comparable to other buyers.

A study of market power of lettuce buyers in California showed that findings were inconsistent with the hypothesis that large buyers exercise oligopsony power in the Salinas lettuce market. The three principal buyers accounted for a relatively small share of the total market. Furthermore, their purchasing patterns did not resemble those which could be expected in an oligopsony market.

To stimulate economic development in the South, producers and processors need information concerning the feasibility of establishing fruit and vegetable processing plants. With funds from the Area Redevelopment Administration, U.S. Department of Commerce, analyses of the economic feasibility of canning and freezing plants as an outlet for vegetables are being completed for northeastern North Carolina, southeastern Missouri, and western Montana.

The increasing importance of processing as an outlet for potatoes and the shifts in potato production areas have had impacts on the structure of the U.S. market for potatoes. A study of the structure of the Red River Valley potato industry disclosed that 852 firms stored some potatoes, but only 295 sold potatoes to customers outside the Valley. All other firms sold to or through the larger shippers. The market power of the large buyers--processors and chains--has led to questions of grower bargaining power.

A study of marketing orders for potatoes has disclosed that average prices received by growers in market order areas have increased relative to prices received in nonmarket order areas. This suggests that these orders are achieving their goal of increasing returns to producers.

In the opinion of tomato growers in Florida, Federal fruit and vegetable marketing orders would function more effectively if: (1) Committees were allowed greater flexibility; (2) provisions were available for controlling volume other than by grade and size; (3) membership was limited to those whose interests lie only in production; (4) violators were more quickly investigated and severely punished; and (5) advertising and promotion were permissible.

Among other developments in the floral industry, the number of retail florist shops increased approximately 3 percent from 1958 to 1963, and the value of sales increased 22 percent. The number of floral wholesalers also increased and sales rose from \$202 million to \$297 million.

B. Prices, Margins, and Costs

In the last decade, prices to consumers for most products of farm origin have risen despite downward trends in farm prices. This widening of farm-retail spreads has brought widespread public concern about the efficiency and performance of the marketing system which culminated in the establishment of a National Commission on Food Marketing.

The Division staff in recent months has answered an unusually large number of requests for information about changes in prices and spreads. In mid-1965, higher food prices were the principal force behind a rising consumer price index. Higher prices for livestock and some fruits and vegetables were responsible for most of the increase; the total farm-retail spread for a market basket of food products was generally unchanged.

In general, farm-retail spreads have widened because of the rising prices of labor and other items that marketing firms buy. However, it is increasingly evident that there is less correlation between short-run changes and farm-retail spreads for individual products and the actual costs of performing marketing services. This results from processing and retailing firms becoming more involved with a multiple-product price concept as these firms extend the number and variety of products and operations. As farmers become more specialized, farmers and their representatives have an increasing interest in prices, returns, and their share of the retail price for a single commodity. Conversely, the processor and especially the retailer have less interest in any single product and more interest in overall gross and net returns on an aggregate or total market basket of foods (often including many nonfarm products).

Special attention in recent months was focused on the price movements of beef, wheat, cotton, and some fresh fruits and vegetables. Reduced supplies of potatoes and lettuce in early 1965 brought sharply higher farm and retail prices.

Potato prices at wholesale and shipping points increased considerably more than at retail. The 1964-65 season average wholesale price for Western Russets in Chicago was \$7.24 per cwt. compared with \$4.31 in 1963-65. The shipping point price was \$5.59 in 1964-65 compared with \$2.56 the preceding season. This means that the grower-packer share increased by \$3.03 per cwt. from 1963-64 to 1964-65, which was more than the increase in retail price. Consequently, the retail spread decreased \$0.75 and the shipping point wholesale spread decreased \$0.10. The producers have benefited relatively more from the price increases than have marketing agents.

Studies of the characteristics of demand for mature green vine-ripened, and greenhouse tomatoes have revealed important implications for producers and marketing firms. Substitution relationships among these products apparently are not of sufficient intensity for any one of the three types of tomatoes to fully and effectively replace the other two.

Studies in Michigan have estimated costs of packing fresh apples and canning red-tart cherries. Under optimum model conditions, apple packing costs would be approximately \$8,000 less per packinghouse than the average under existing methods and scale of operation.

C. Location and Interregional Competition

As farm production shifts from one area to another, marketing firms must adjust to the new environment. New firms may be called for in one area while those in other areas must seek other opportunities. Changing transportation rates put one area at a competitive disadvantage compared to others both in production and marketing. Marketing economic studies emphasize the changes taking place and the scope of adjustments needed to meet them.

Transportation of exempt commodities has been shifting from rail to truck. Between 1955 and 1963, the share of total fruit and vegetable traffic from California carried by trucks increased from 19 to 34 percent. Much of the truck transportation was for relatively short hauls. The balance between the number of incoming and outgoing loaded trucks from California varied among different regions considerably, thereby resulting in different costs of truck transportation between the different regions and California points.

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COMMODITY SITUATION AND OUTLOOK ANALYSIS

Economic and Statistical Analysis Division, ERS

Problem. Prices to producers are relatively unstable and conditions of agricultural production are changing rapidly. Thus, the farmer stands in special need of frequent accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for making sound production and marketing decisions. It has long been a goal of the Department to provide the farmer with economic facts and interpretations comparable to those available to business and industry. Such information is provided through a continuous flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting major farm commodities. The outlook program was strengthened during the year by extending the quarterly Outlook Digest to a monthly basis, to permit timely reporting of significant changes which may occur between issues of the various commodity Situation reports.

USDA AND COOPERATIVE PROGRAM

The program includes a continuous appraisal of the current and prospective economic situation of the major crop and livestock items. These appraisals, developments of interest to the industry, and results of special studies are published 4 to 6 times a year in the various commodity Situation reports, with brief resumes in the quarterly Demand and Price Situation and the National Food Situation, and when appropriate in monthly issues of the Farm Index and the Agricultural Outlook Digest. Comprehensive analyses of the current and prospective situation are presented for each of the major commodities at the Annual Outlook Conference, and more limited appraisals given at regional and State conferences and at meetings with industry groups. Special analyses are prepared from time to time on the probable effect of proposed programs on the supply, price, and utilization of the various commodities. Basic statistical series are developed, maintained, improved, and published for general use in statistical and economic analysis. Statistical Handbooks are published periodically for livestock and a number of field crops.

Except for a Regional Field Office for livestock, in Denver, Colorado, all the USDA situation and outlook work is carried on from Washington. The regional livestock project is a cooperative effort including this Division, the Federal Extension Service, and State Extension Services in the Western States.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend on the U.S. Department of Agriculture for the yearly across-the-board commodity situation and outlook research. There is increasing interest in longer range price prediction because of the growing specialization of farms, which makes yearly enterprise shifts less common and less feasible, and which calls for large capital commitments over longer periods of time. The State extension staff members supplement and adapt such research information to meet the commodity situation of their States.

The total direct research effort in the situation and outlook area is small--probably no more than 2 to 3 professional man-years. While not designated as outlook research, much of the research conducted by the experiment stations and reported elsewhere contributes to improved understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Fruits and Tree Nuts

A special section on noncitrus fruits in the June 1964 Fruit Situation was followed by a similar article on citrus fruits in October. These presentations summarize the market position for processed fruits and give background information on production and utilization of fruit crops.

The geographic importance of U.S. fruit and nut production was examined and appraised on the basis of both quantity produced and value of production, basis the 48 Mainland States. Results were summarized in the special article in January 1965.

Fruit tree censuses made in 10 apple States since 1960 were analyzed and results published in another article in January 1965. The census data revealed a high proportion of young trees, recent heavy plantings of dwarf-type trees, and the increasing importance of Red Delicious and Golden Delicious varieties of apples.

Plum and prune industry trends over the past 30 years and prospects for the future were summarized in a special article in June 1965. Changes in plum and prune production, varieties, uses, and consumption were discussed.

"Trees, Apples and Population in 1970" was the subject of a leading paper presented at the 30th Annual Meeting of the National Apple Institute, Sun Valley, Idaho, June 24-27, 1965. This paper, prepared at the request of the National Apple Institute, pointed to the increasing emphasis in new plantings of dwarf-type trees and highly colored varieties, to a westward shift in production, and to prospective increases in apple production at a faster rate than population growth.

Tables on supplies and distribution of fresh fruits were revised to embody new data on banana imports. This change recognizes the recent transition from stems to boxes in shipping this fruit.

Vegetables and Potatoes

Because of continued widespread interest in the changing pattern of potato utilization, attention was given to developing and refining statistical series on consumption. The studies indicated sharp gains over the past 15 years in processed potato use, particularly of potato chips and frozen potato products. The heavier use of processed potatoes occurred at the expense of sales to fresh market outlets; consumption of fresh potatoes per person declined nearly a fifth during the last decade, falling to an alltime low in 1964. Other work on potatoes included development of a stocks-disappearance ratio for frozen potatoes which provides a means of evaluating market conditions in the processing industry and the potential effect on the overall potato price structure.

Analyses were prepared for the Secretary's office on the probable effect of proposed Government programs on acreage, production, utilization, price, and farm income of dry edible beans and dry peas.

In cooperation with specialists in other agencies of the Department, a special report was prepared for the Committee for Agriculture of the Organization for Economic Cooperation and Development concerning the fruit and vegetable industry in the United States. The report analyzed major aspects of the domestic industry including trends in acreage, production, utilization, and consumption; foreign trade; changes in the production and marketing structure; and government services and activities affecting the U.S. horticultural industry.

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION --
HOUSEHOLD AND INDUSTRIAL

Standards and Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for consumers to express to producers either pleasure or displeasure with available merchandise. To market agricultural products more effectively, it is necessary to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on consumers' attitudes toward old and new product forms of agricultural commodities, preferences, levels of information or misinformation, satisfactions or dislikes, and what product characteristics would better satisfy current consumers and/or attract new ones. It is also important to know the relationship between the consumption of one agricultural commodity and another in consumers' patterns of use, the relationship between agricultural and nonagricultural products, and probable trends in the consumption of farm products. Producer and industry groups as well as marketing agencies consider such information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increases returns to growers.

USDA PROGRAM

The Special Surveys Branch conducts applied research among representative samples of industrial, institutional, or household consumers and potential consumers. Such research may be conducted to determine preferences, opinions, buying practices, and use habits with respect to various agricultural commodities; the role of competitive products; acceptance of new or improved products; and consumers' ability to discriminate among selected attributes of a product or levels of an attribute, and the preferences associated with discriminable forms.

In addition to the studies of consumer preference and discrimination, the Branch also provides consultants and conducts special studies, upon request, for other agencies in the USDA or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The research is carried out in cooperation with other USDA or federal agencies, State experiment stations, departments of agriculture, and land-grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology or other social sciences, in Washington, D.C., which is headquarters for all the research whether it is conducted under contract or directly by the Branch. The Federal scientific effort devoted to research in this area during the past year totaled 7.0 professional man-years. An additional man-year was devoted to research conducted under a transfer of funds arrangement.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Consumer Preference

Noncitrus fruit. A preliminary report has been published, and a final report presenting more detailed findings is in preparation on a nationwide contract survey among homemakers to ascertain the frequency and patterns of use for selected noncitrus fruits as well as the attitudes and opinions which influence their use or nonuse.

All homemakers were asked which of the following fruits they had purchased in the past 12 months. More than 80 percent of the homemakers said they had bought fresh bananas, apples, grapes, and peaches. Between 40 and 70 percent had purchased fresh pears, plums and prunes, sweet cherries, and nectarines. Less than 30 percent had bought fresh pineapple and apricots.

Respondents were asked what they thought a store manager could do to get customers to buy more fruit. Nearly half the homemakers feel consumers would buy more if stores displayed higher quality fruits. About 1 in 4 feel more attractive displays or lower prices would increase sales.

Homemakers usually prefer to purchase unpackaged fruit. Buying loose fruit permits homemakers to select the number and size they want and to inspect the fruit for bruises and spoilage. However, many mentioned the advantages of packaging; it is time saving and sanitary.

Potatoes, rice and wheat. A contract has been signed with a private research firm to collect information from a nationwide sample of homemakers on their use of and opinions about selected potato, rice, and wheat products. The study is designed to ascertain household consumers' preferences and buying practices for these commodities, including specialty or highly processed convenience-type food products, and to identify the characteristics which consumers consider to be important in selecting such food products and to determine their satisfaction with items currently available. The field work on this study is planned for the fall of 1965.

B. Quality Discrimination

The sensory testing laboratory of the Branch is used to ascertain, under controlled conditions, people's abilities to discriminate among qualities or levels of a quality for food samples, or other sensory or visual stimuli, and the preferences associated with discriminable variables. The products which have been evaluated include new food forms developed in the ARS laboratories or variations of products already available. Studies have been

conducted this year on apple juice, milk, and an apple-grapefruit juice blend. Studies on Hawaiian coffee are in progress and research on grapes is planned. Some examples of the types of problems investigated are listed below. The results of these studies have not been published, but were reported by memorandum to the cooperating group requesting the research.

Apple juice. People's preference for six apple juices, including an experimental type 6-to-1 concentrate, were determined under normal and under greatly reduced illumination. The experimental juice was liked as well as the controls under both lighting conditions.

In a related study, people rated two cloudy and two clear apple juices on their appearance. The clear apple juices were judged to be of better quality than the cloudy ones.

Blended juices. Research has been conducted on people's preference for different proportions of apple to grapefruit juice in a blend. Preference for an apple-grapefruit juice blend has also been compared with that for commercial blends, orange-grapefruit, pineapple-grapefruit, currently on the market. Data from these studies are being analyzed.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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IMPROVEMENT OF CROP ESTIMATING PROCEDURES

Standards and Research Division, SRS

Problem. The Statistical Reporting Service produces a large number of current statistics pertaining to agriculture. Because of limited resources, statistical methods were devised with a view to producing the most information for the least cost. These methods are subjective in nature and are based largely upon self-selected samples from voluntary crop reporters who fill out and return mailed questionnaires. The information is generally collected in the form of relatives such as acres this year compared to last, and crop condition as a percentage of full crop. Persistent bias is removed by charting, and census or other check data are generally projected to form current estimates. Estimates based on these sample methods have proved relatively satisfactory over the years. However, in seasons when changes are unusually large, the changes may not be fully reflected in the appraisals and reports of the respondents to mailed questionnaires. In situations like this, when accuracy is needed most, the estimates may lack the required precision. Then, when the estimates are translated into available supplies for the different commodities, price inequities may occur and, as a result, producers or the processors of agricultural commodities may suffer serious financial loss.

With the development of modern statistics, new methods based upon probability sampling have been developed. Although surveys based upon probability sampling are more expensive to conduct than the traditional self-selecting mailed survey, these new methods offer a means of increasing the precision and reliability of the estimates. Because of the need by the agricultural economy for high quality statistics, it is mandatory that the statistical theory and methods be developed and adapted to the collection of agricultural statistics. Some of the new procedures have already been introduced but there is an urgent need for a continuing research to devise efficient survey methods so as to make possible continuing improvement in the quality of SRS statistics.

USDA PROGRAM

The Department of Agriculture conducts a program of applied research designed to strengthen and improve the methodology used in collecting agricultural statistics. The principal disciplines involved are mathematics, statistics and probability, but other disciplines relating to a particular problem are brought to bear as required. Examples of these are plant physiology, psychology, cartography and photogrammetry. The current program consists of 6.0 professional man-years per year devoted to the study of sample and survey methods, and 4.0 professional man-years working on methods for forecasting and estimating the yields of important crops. Work under this program is done in Washington, D. C., and in SRS field offices located in the States concerned.

Research objectives in survey methods are concerned with the improvement of all aspects of survey design. These include questionnaire and form design, universe definition and sampling frame construction, sample design and estimators, enumeration techniques, quality checks, editing procedures, methods of processing data and the post-analysis of the survey with a view to improvement of design. Response errors are being studied. Here the objective is to establish communication with the respondent through the medium of a questionnaire which will transmit concepts with a high degree of fidelity and at the same time induce the respondent to reply, and reply honestly and fully. An attempt is being made to distinguish between those items for which the respondent has accurate knowledge, those items which he may have once known but no longer recalls accurately, those items which he had never known precisely, and those items for which he is unwilling to divulge information or gives deliberately misleading information. Where applicable, alternative sources of information will be sought and different ways of motivating respondent cooperation will be tested.

Work on objective yields is being continued. This includes the refinement of the forecasting models being tested as well as the development of forecasting procedures for other important crops including apples and onions.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Onions. Objectives of the 1964 study of onion development in Michigan were to investigate methods of determining and defining state of maturity and to establish a growth curve. Analysis of 1964 weekly development data opened several new areas of interest. It was thought that dry matter might be used to determine stage of maturity. It turned out that the percent dry matter content in onions is nearly constant regardless of the size or stage of maturity of the onion. Bud formation was also studied with the idea that the number and size of buds in immature plants might have an effect on the weight of the bulb at maturity. Here it was found that the development of buds varies not only between varieties but within the same variety. The variation in number and size of buds at a given stage of development was too great to give a valid indication of final bulb size. Grouping of bulbs from each weekly sample into 3 size groups, less than 1 inch, 1 to 2 inches, and 2 inches plus, proved to be a good procedure for analysis of the growth pattern over the season. The addition of the 1964 weekly data to previous years data pointed out the need for more work to stabilize the late season growth pattern. From this work it appears that the best method of determining maturity is date of planting and days after planting for a given variety or perhaps a group of varieties.

During 1965 the program was continued by using three of the varieties that had been planted in past years. Location and planting dates were also comparable to 1964. New items of study include field stratification, based on row density, to aid in stabilizing the late season growth curve. Data on leaf count and height and diameter of the plant at the bulb juncture are being collected to determine their relationship with bulb weight.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

